FORECAST: METEOR STORMS • ASTRONOMY GIFTS

Astronomy®

HDG 08070

November 1998 • $4.50
U.K. £2.40
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When Big Stars Pop!

Supernovae Scatter Fresh Seeds of Life

Reflections of a Mirror Maker

Discovering Infant Solar Systems

MEADE LX50

Advanced technology at the most affordable prices *ever.*

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photoguide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four- speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

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$495!

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

MEADE LX50 EMC
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Meade
Meade
7"
10"
8"

MEADE LX200

The largest-selling serious telescopes in the world.

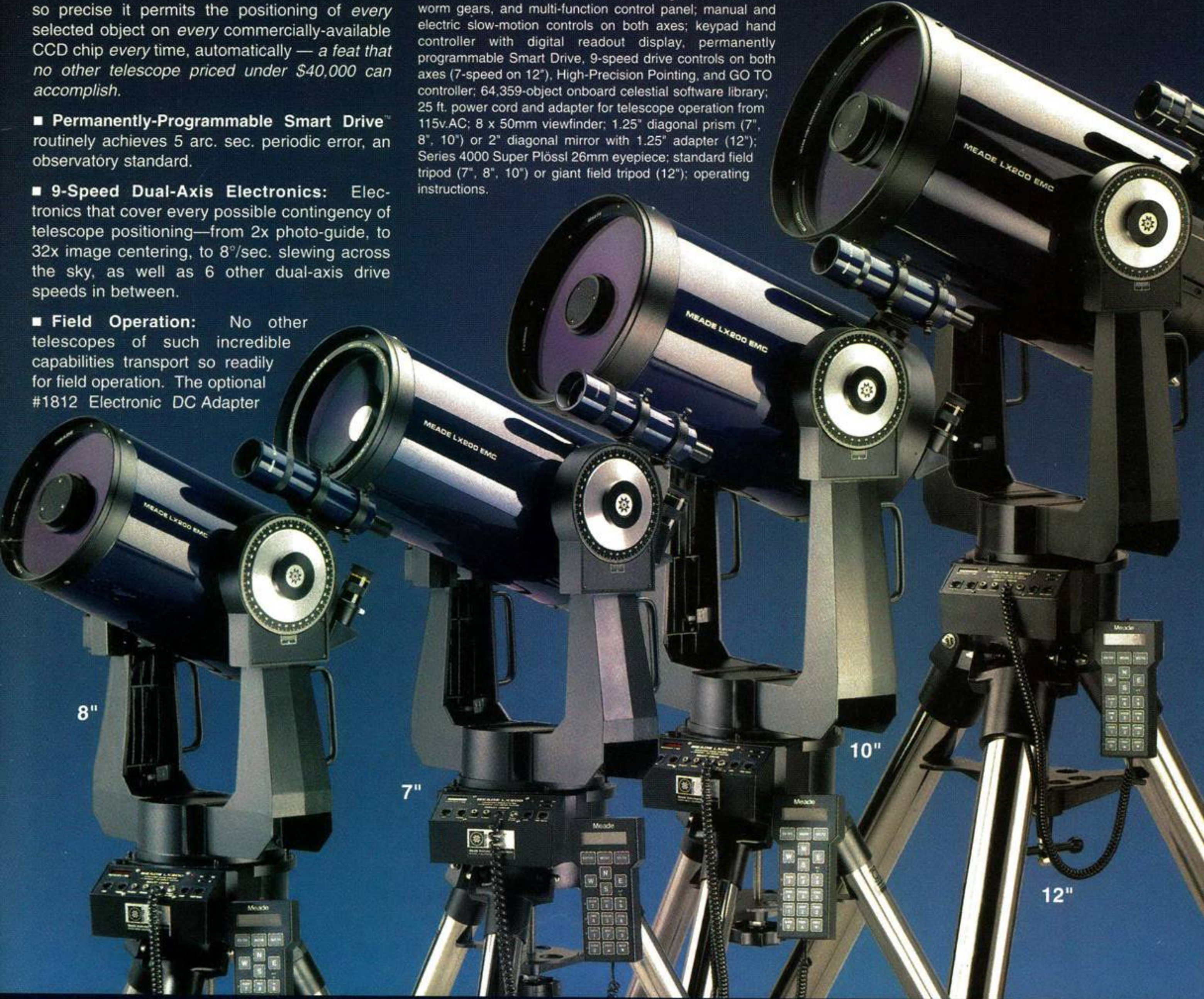
In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*
- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.



Write, call, or fax Meade Instruments for your free copy of the 100-page Meade General Catalog.

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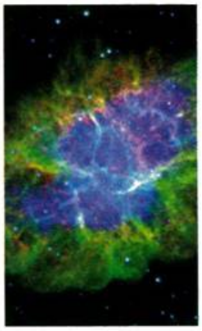

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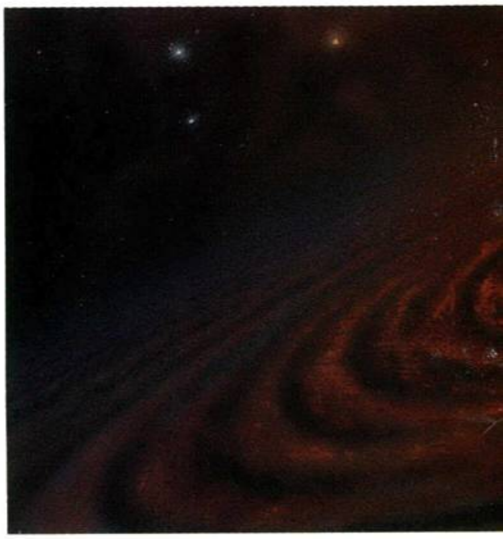

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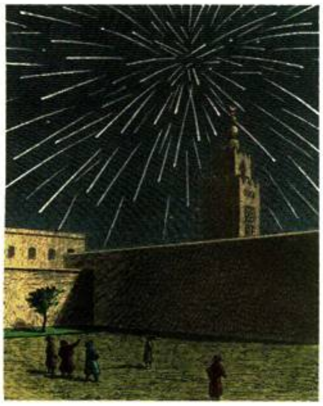

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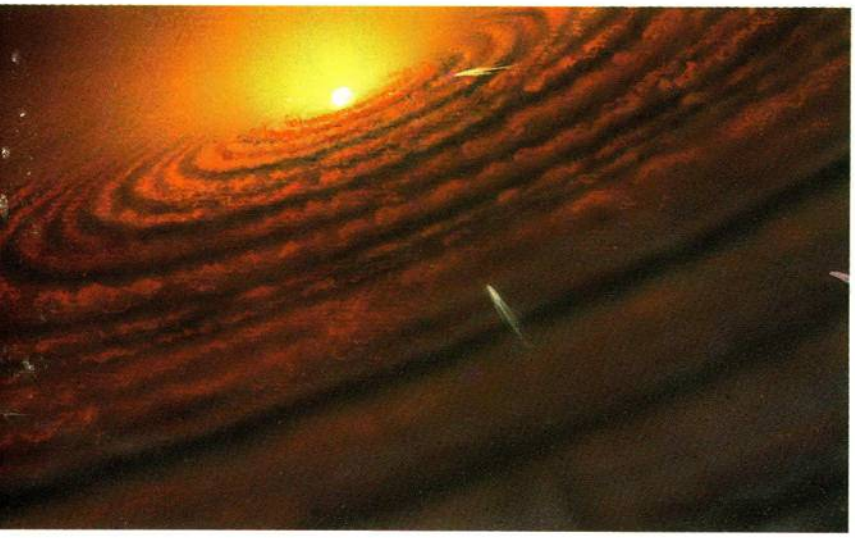

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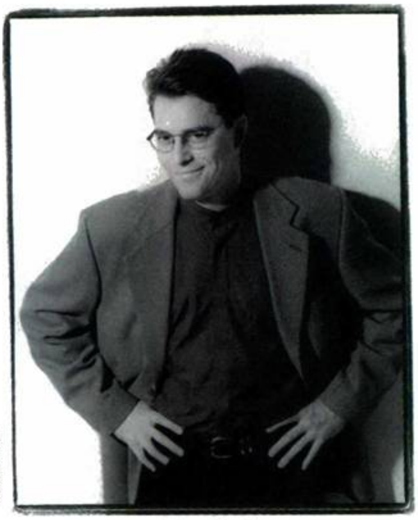
BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Telephone Pressures

A few *Astronomy* subscribers have alerted us to a company that is fraudulently calling to ask them to renew their subscription to our magazine. The callers pressure readers to renew over the telephone by credit card. *Astronomy* doesn't use telemarketing to renew subscribers. Although our customer service representatives happily take orders for the magazine by telephone, no one from *Astronomy* magazine uses the phone to solicit subscriptions. So if you get a call from someone who offers you a discounted price, don't provide them with your credit card information.



Francis Ford

Tom Ford

If you ask the phone solicitor to send an invoice, he will — reluctantly. This is another clue that the offer isn't legitimate. Unlike most magazine companies, we handle our subscription fulfillment right here in Waukesha, Wisconsin, where we produce the magazine. If you ever have a question regarding your renewal, please call our customer service number at 1-800-446-5489.

On another, much happier note, we want to introduce you to our new assistant art director Tom Ford, who will be helping Carole Kramer design stories for your delight and information. He is Milwaukee born and educated — with a commercial arts degree from Milwaukee Area Technical College. He will be replacing designer Kathy Kolstedt, who is leaving us for a new life in Texas. We will miss her.

Tom has worked as a book designer for Western Publishing, which produces Golden Books, and as magazine designer for *Earth* and *Art Muscle*. Unlike many *Astronomy* staffers, Tom says, "I'm not a dog person," but he loves his cats Anastasia and Crystal. He is an avid dancer and swings through the local clubs with his regular partner Carmen Nickerson, a professional singer.

Astronomy.

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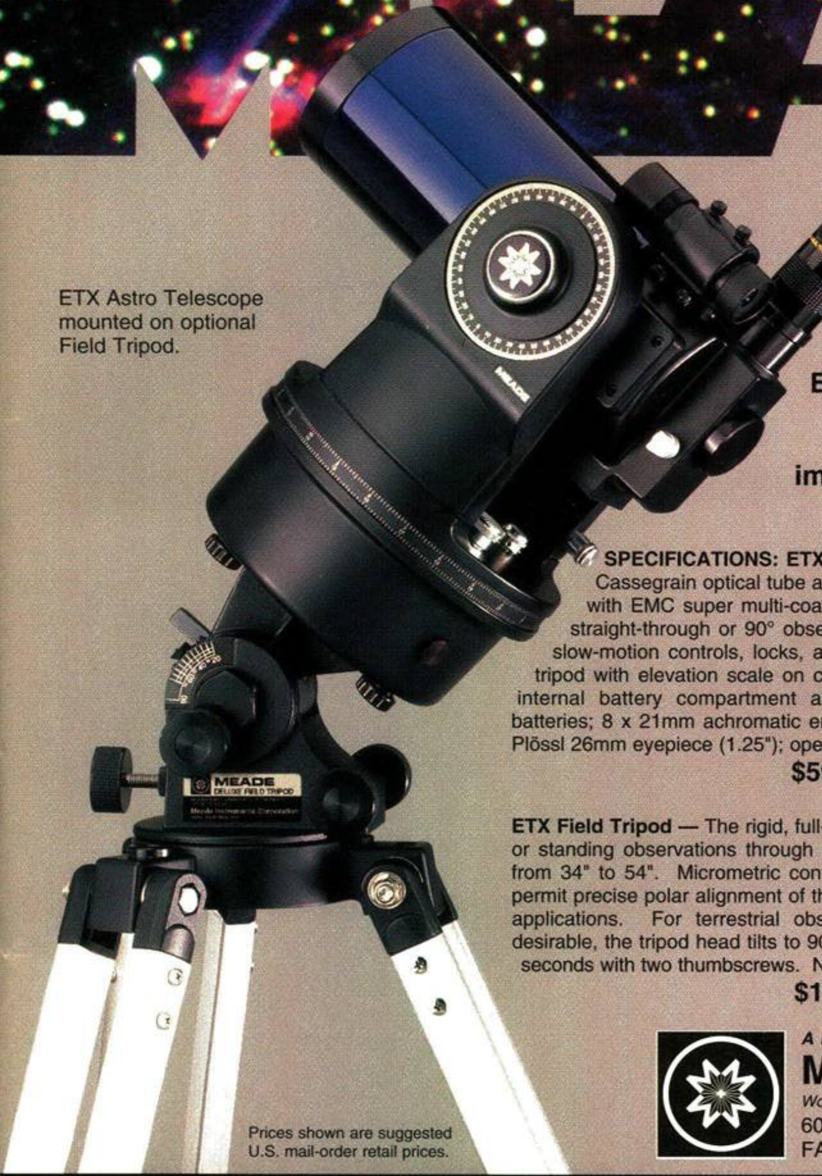
MEADE ETX™

Diffraction-limited imaging and ultraportability ...at only $595, complete!



ETX Astro Telescope mounted on optional Field Tripod.

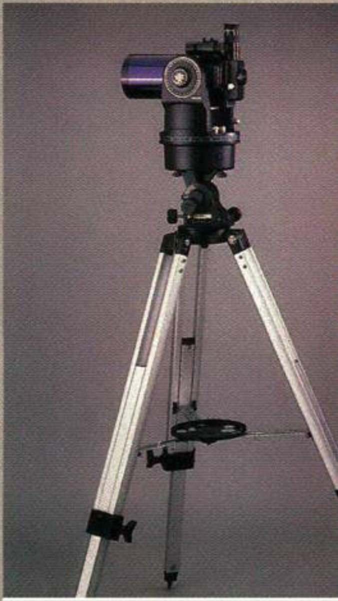
The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

SPECIFICATIONS: ETX Astro Telescope — Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. Net weight 9 lbs.

$595 (+ $20 packing & shipping in the 48 states)

ETX Field Tripod — The rigid, full-length ETX Field Tripod allows for seated or standing observations through the telescope; tripod height is adjustable from 34" to 54". Micrometric controls in both azimuth and elevation-angle permit precise polar alignment of the telescope's fork mount for astronomical applications. For terrestrial observing, where altazimuth orientation is desirable, the tripod head tilts to 90°. The telescope attaches to the tripod in seconds with two thumbscrews. Net weight 11 lbs.

$169 (+ $10 packing & shipping in the 48 states)



Tilt and lock the ETX Field Tripod to 90° for terrestrial observing.

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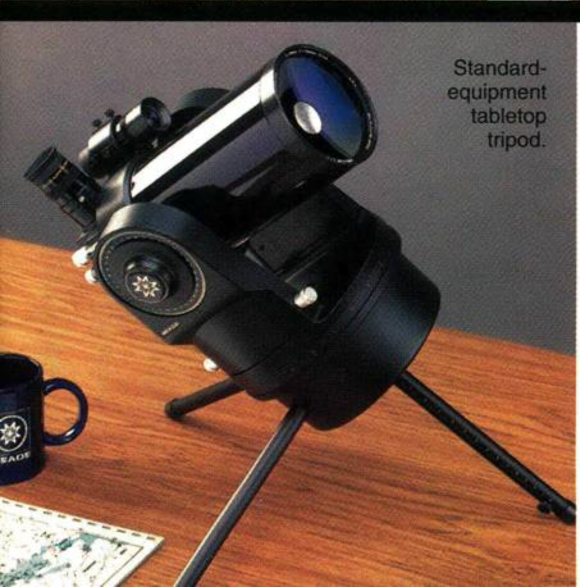
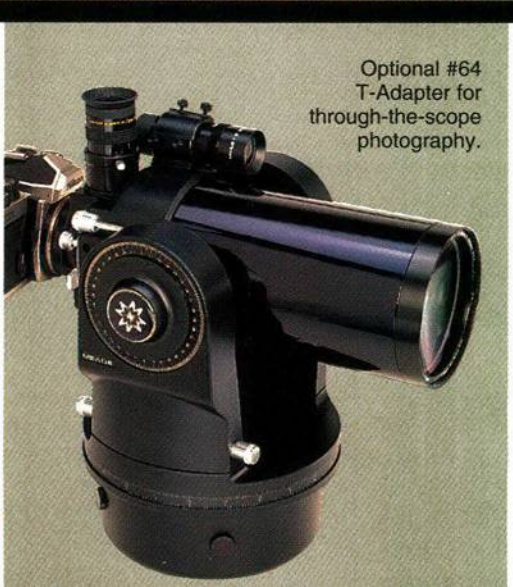


Standard-equipment tabletop tripod.



Optional #64 T-Adapter for through-the-scope photography.

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LUMICON, Livermore, CA.
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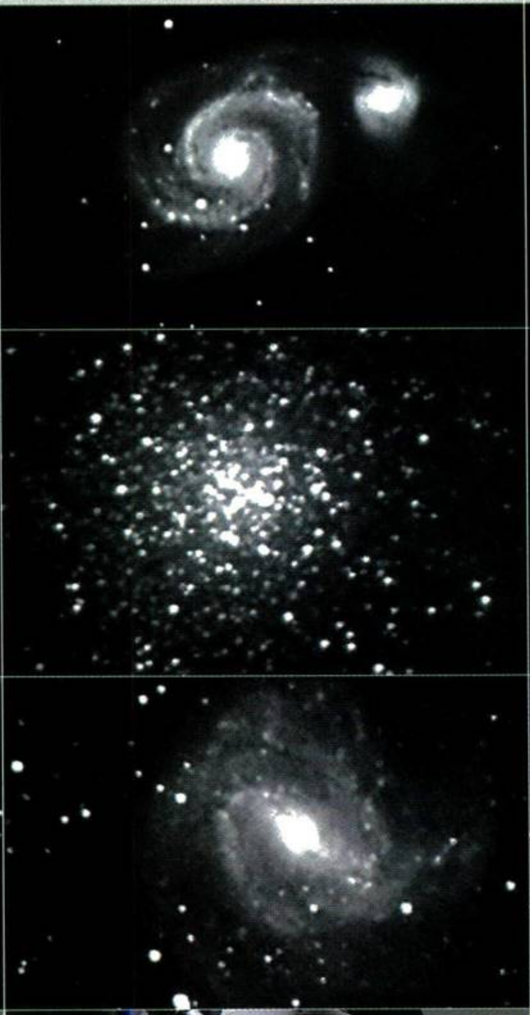
MEADE® PICTOR™ AUTOGUIDER/IMAGERS

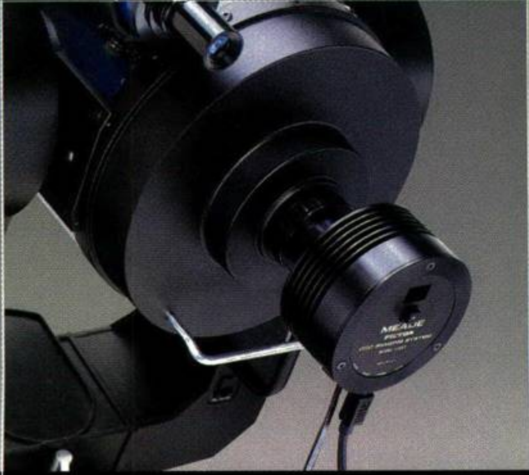
Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.

Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



Pictor 416XT images: Saturn (in green light), 16" LX200, Dr. Donald Parker; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Crab Nebula (M1), 25" reflector, Jack Newton.

Pictor 208XT: $495 ***complete***



Pictor 216XT: $695 ***complete***

Shipped **FREE** with Pictor 201XT Autoguider, CCD Off-Axis Guider, Image Orienter, and Epoch 2000ip Image Processing Software, as shown!

Pictor 416XT: $1695 ***complete***

includes $800 Meade CCD Equipment System

Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. ***For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 100-page Meade General Catalog.***

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Model 102ACHR/500:
4" f/9 Achromatic
Refractor — **$995.**

Model 114NT/500:
4.5" f/8 Newtonian
Reflector —
$595.

Model 127NT/500:
5" f/8 Newtonian
Reflector — **$695.**

Model 102APO/500:
4" f/9 *ED* Apochromatic
Refractor — **$1695.**

Model 203SC/500:
8" f/10 Schmidt-
Cassegrain
— **$1295.**

Shown with optional #1702 Dual-Axis Drive System

MEADE 500-Series

Experience all of the high-resolution optical performance and mechanical precision of a MEADE reflector, refractor, or Schmidt-Cassegrain, at a moderate pricing level. Each complete 500-Series model includes the all-new MEADE LXD 500 equatorial mount with dual-axis worm gears, engraved setting circles, micrometric slow-motion controls in RA and Dec, rigid aluminum tripod, and a full complement of accessories. Choose from among five models the one that's right for your budget and observing requirements. *For complete details send for your free copy of the Meade 100-page General Catalog.* Optional systems for Meade 500-Series telescopes include:

#1701 Single-Axis RA Drive System	**$145.**
#1702 Dual-Axis Drive System, with 4-speed hand controller	**195.**
#812 Polar Alignment Finder	**49.**

Prices shown are suggested U.S. national mail-order retail prices.

Packing and shipping: 4" models—$55; 4.5" and 5"—$45; 8"—$65.

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STARFINDER DOBSONIANS

Now with Series 4000 Super Plössl 26mm eyepiece as *standard equipment!* Consider these features:

Series 4000 SP26mm Eyepiece (1.25"): The premium SP26mm ocular permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities. This $80 eyepiece is now **standard-equipment** on all Meade Dobsonians.

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: The same strong, spiral-wound Sonotubes™ used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

$270 Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

- **1 - Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*
- **1 - Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*
- **2 - Meade Series 4000 Super Plössl 9.7mm and 26mm** multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

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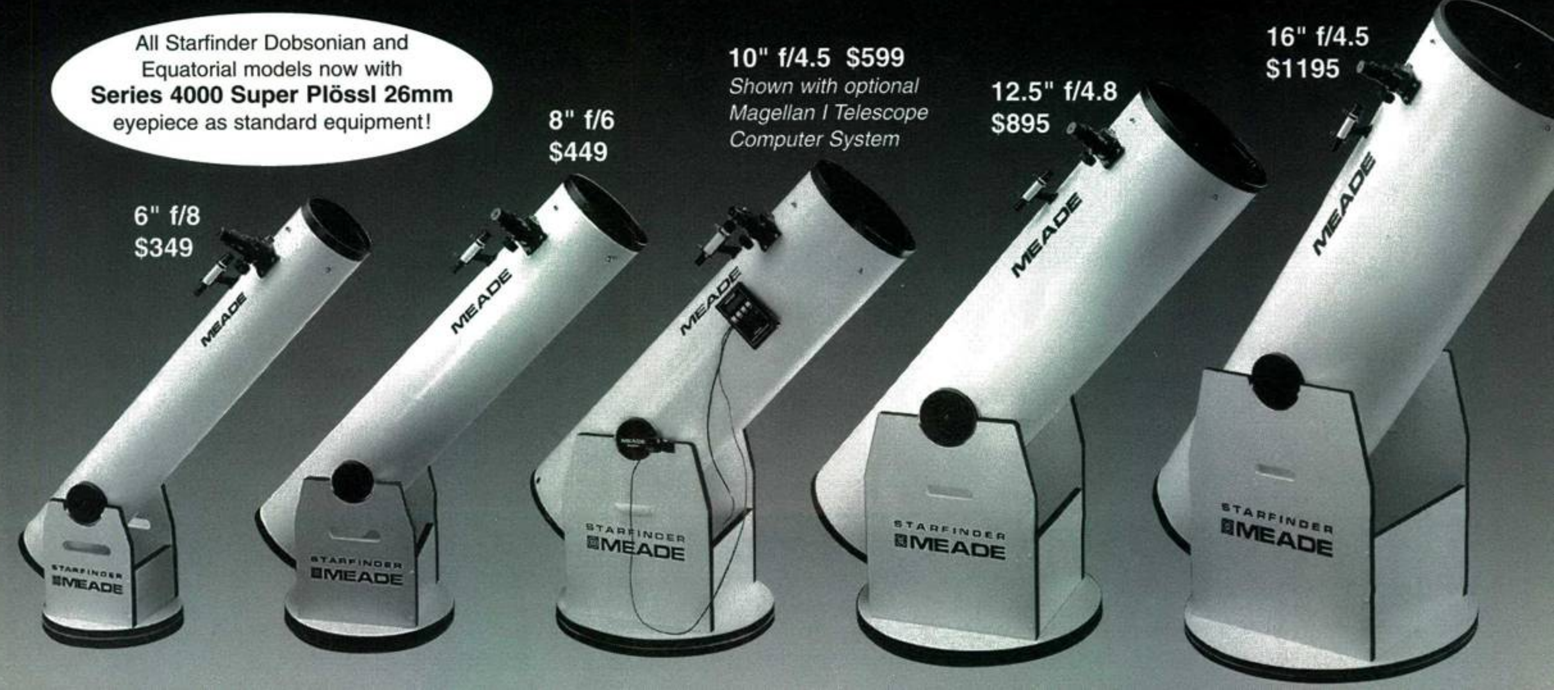
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES *Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.*


All Starfinder Dobsonian and Equatorial models now with **Series 4000 Super Plössl 26mm** eyepiece as standard equipment!
6" f/8 $349
8" f/6 $449
10" f/4.5 $599 *Shown with optional Magellan I Telescope Computer System*
12.5" f/4.8 $895
16" f/4.5 $1195
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MEADE
STARFINDER EQUATORIALS

With DC-powered drive systems for automatic tracking and Series 4000 Super Plössl 26mm eyepiece.

***Pro**fessional-Grade Optical System:* Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); #637 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

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MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" .... $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" .... 295.

MEADE
MAGELLAN II
COMPUTER · CORRECTOR
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Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" .. 495.
#2019: for (DC-powered) Starfinder Equatorial 16"........ 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

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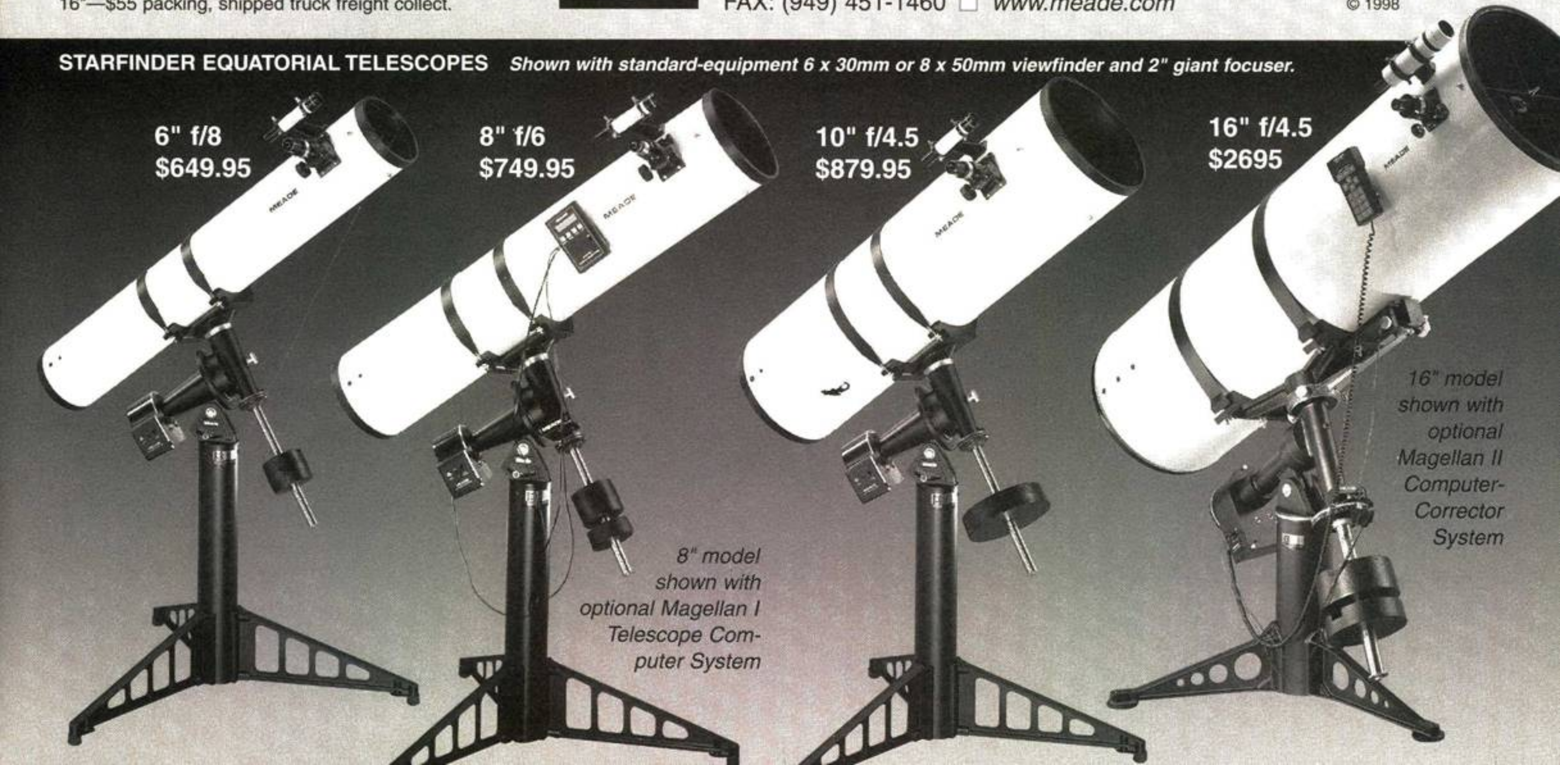


STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***

6" f/8
$649.95

8" f/6
$749.95

10" f/4.5
$879.95

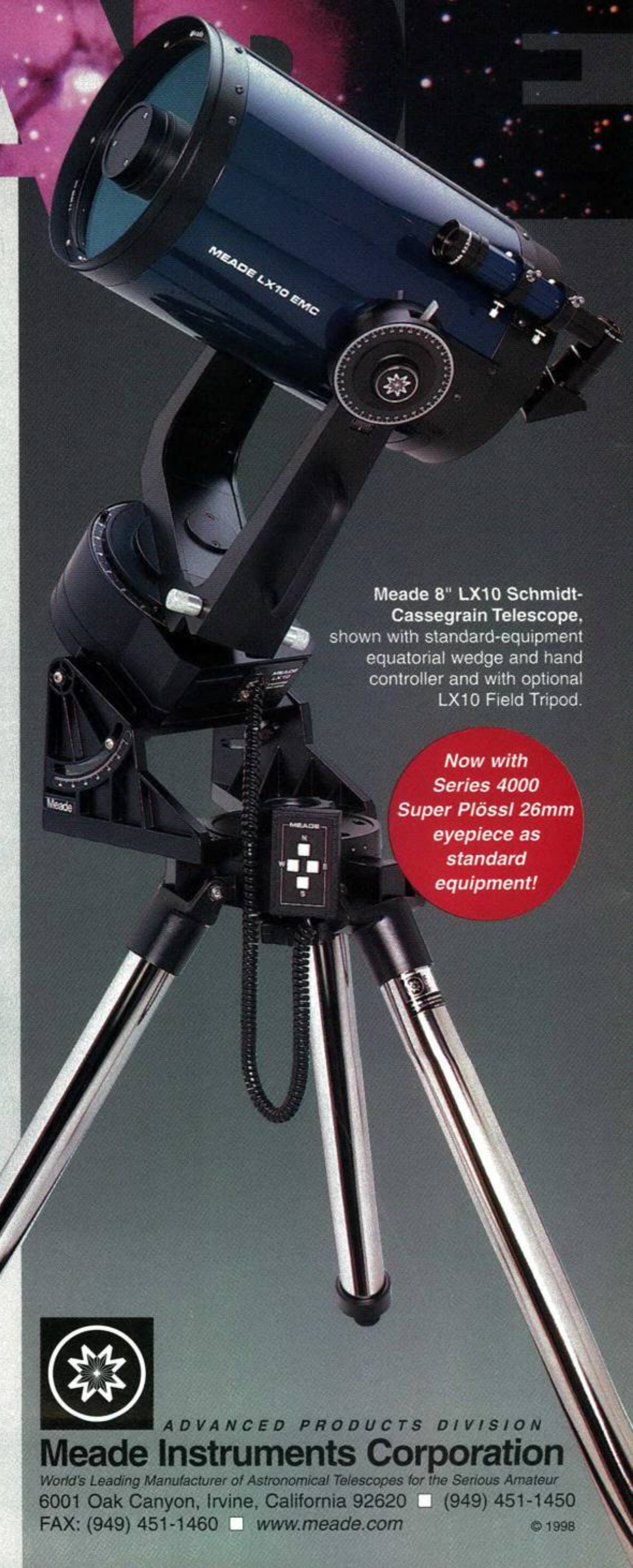
16" f/4.5
$2695

8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

8" LX10
8" LX10 DELUXE

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only $995!



Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

Now with Series 4000 Super Plössl 26mm eyepiece as standard equipment!

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super-Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Series 4000 SP26mm eyepiece:** Complements the exquisite imaging of Meade 8" SC optics. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed; and (c) Meade Epoch 2000 Jr. Sky Software with 10,000-object database — all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; Meade #544 8 x 50mm achromatic viewfinder in place of 6 x 30mm viewfinder; and Meade Epoch 2000 Jr. Sky Software with 10,000-object database.

$1149. (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	**195.**
Electric Declination Motor System for LX10	**95.**
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	**375.**

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MEADE RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm each: **$79.95** (4.54)

32mm (52°); **40mm** (44°) each: **99.95** (5.26)

56mm (52°; 2") **199.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

Series 4000 Zoom Eyepiece

New!

The first zoom eyepiece—ever—to yield absolutely uncompromised resolution, color correction, and image brightness. Includes 8 elements, zooms from 7.7mm to 23.1mm with pinpoint imaging from edge to edge. Fully multicoated optics permit 99.8% light transmission at each air-to-glass surface. Apparent field 62° at 7.7mm; fold-down rubber eyecup; threaded for filters; 1.25". **$295.** (7.02)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (4.54)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25". **$59.95** (4.54)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces). **$42.95** (3.86)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25". **$149.95** (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$129.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A **49.95** (4.54)

Set #2–4 filters: #11, #25A, #47, #82A **49.95** (4.54)

Set #3–4 filters: #8, #21, #38A, #56 **49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.** each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera. **$39.95** (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera. **$39.95** (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera. **$26.95** (3.86)

Series 4000™ 2x Apochromatic Barlow Lens

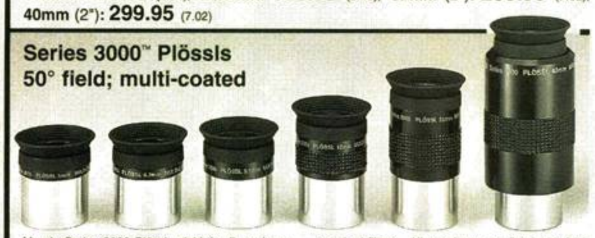
#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm. **$79.95** (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls 50° field; multi-coated



Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B

#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia. **79.95** (4.54)

#910B–Threads into 2" eyepieces, 44mm dia. **119.95** (5.26)

#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (5.26)

#908N–Threads into 1.25" eyepieces, 26mm dia. **89.95** (4.54)

#910N–Threads into 2" eyepieces, 44mm dia. **129.95** (5.26)

#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (5.26)

New!

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia. **99.95** (4.54)

#910X–Threads into 2" eyepieces, 44mm dia. **159.95** (5.26)

#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **149.95** (5.26)

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Bravo Astroscan 2001

I enjoyed reading your article "The Little Scope that Could," (May 1998). As an Astroscan owner, I could not agree more with the praises sung on its behalf.

I purchased my Astroscan in 1979 and for three years it was my main telescope. I spent many nights looking at the wonders it could show me. When my husband first looked through it at the moon he was floored to discover he could see craters. Night after night I showed him more of the moon and many other objects.

Telescopes come and go in my life, but I would never willingly part with the Astroscan. It has come in handy many times over the years, for instance when I was in a hurry to set up a scope to observe an occultation of Saturn by the moon.

By the time I joined the Los Angeles Astronomical Society in 1987, I had tried astrophotography, beginning with the Astroscan. On this page is my first photo — not just the first successful one, but the first one from the first roll. It was the January 1986 full moon rising behind a small bank of clouds. I set up a homemade tripod, built for a 35mm movie camera, and firmly attached the tripod adapter to it with the telescope attached to that. I used the 28mm RKE eyepiece and the Edmund Variable Slide Tube Camera Adapter. Then, using the controls on the tripod, I aimed at the moon and became an astrophotographer.

Whenever I give a slide presentation at the Griffith Observatory, I end with this picture. It was my first and it's still my best. I put the picture on a coffee mug, which I use every day. Each time I drink coffee I remember that night and many others. This little telescope opened up the wonders of the night sky to me.

It was easy to pick up the telescope and cradle it in my arms, then pick up the rubber mat, the piece of felt to protect the car, the stand, the box of eyepieces, my small notebook, and my flashlight before heading out to the street, the driveway, or the backyard table. I didn't get the finder for a couple of years, instead I learned to find things in the sky without it — the Sombrero Galaxy, the Coathanger, many double stars, clusters, Jupiter, Saturn, Venus, the endlessly fascinating moon, and (with a solar filter) the sun. For quick setup, wide fields, and ease of operation, you can't beat the Astroscan 2001. — *Shirley Sunada, Monterey Park, California*

The moon (with intervening cloud cover) shot through an Astroscan 2001. Shirley Sunada

Space Ornithology

It was a treat to read Nancy L. Hendrickson's update on the status of space ornithology ("It's a Bird . . .") in the July 1998 issue of *Astronomy*. Use of the term "birds" by satellite controllers was well established by August 1967 when I reported for my first space operations assignment as weather satellite orbital analyst at Offutt Air Force Base in Nebraska.

I believe, though, that the term "space birds" originated in 1987 when I produced a PC-DOS computer program of that name, shortly after presenting a paper on the visibility of artificial Earth satellites at the AAS/AIAA astrodynamics specialist conference in Kalispell, Montana. I had conceived of and implemented an early version of the program while teaching mathematics at the Air Force Academy in 1973. I used the program to predict the local visibility of the Skylab space station. As it was the same year that Steven A. Walther founded *Astronomy* magazine, 1973 was indeed a very good year. (I became a charter subscriber and, yes, I still have that August 1973 first issue.)

Space Birds received a favorable review in *Astronomy* (July 1990, page 92) and enjoyed modest sales from 1988–1991, during which time I published the quarterly *Space Ornithology Newsletter*. Since then, though, my own interests have changed slightly and satellite tracking is less of a focus.

So whose program do I recommend today for making satellite visibility predictions? My pick is *SatSpy* by David A. Cappellucci, as mentioned in Ms. Hendrickson's article. *SatSpy* has impressive graphics and sound orbital mechanics. I know, because Dave was one of the top students in the graduate-level orbital mechanics course that I taught for CU-Colorado Springs in 1984. — *Roger L. Mansfield, Larkspur, Colorado*

I was disappointed that Nancy Hendrickson failed to mention my satellite tracking program, STSORBIT PLUS, usually known as STSPLUS. STSPLUS is used throughout NASA, USAF, ESA, and RSA as well as by thousands of people worldwide. STSPLUS also is the only readily available software used on board the Russian Mir Space Station. The program and current orbital data ("TLEs") are available for free download from my home page, http://www.dransom.com. — *David H. Ransom, Sedona, Arizona*

After reading Nancy Hendrickson's article in the July issue, I felt compelled to "talk back." I agree with her that many people, not just amateur astronomers, observe and perhaps

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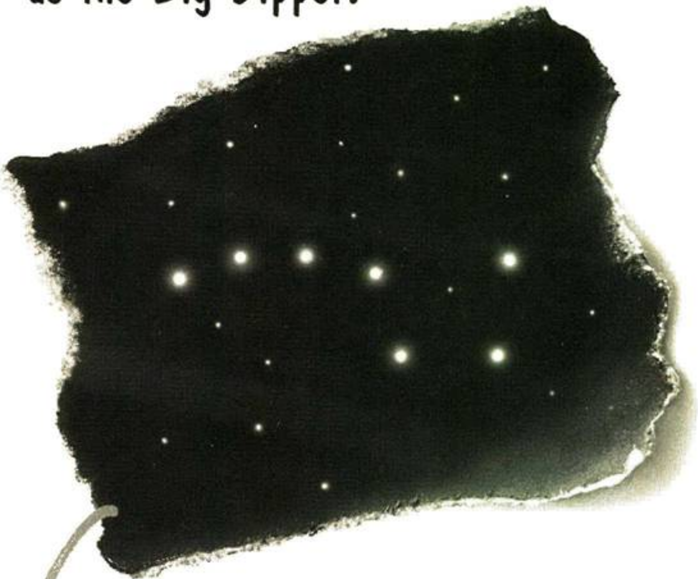

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study these moving lights in space called satellites.

Hundreds of satellites serve humankind in beneficial ways. For example, weather satellites track storms and help meteorologists warn the public of dangerous weather. Satellites also help governments spy on each other "in order to maintain peace."

Nonetheless, I question the need (rather the want) for new communications satellite networks such as Iridium. Iridium is the first of many such systems planned for low-Earth orbits. Currently we have more than 800 satellites in space. How essential is it to use them to download information from the Internet in microseconds rather than seconds? Not only are we filling space with lots of garbage, but this garbage also reflects light. Radio astronomers are having fits as satellite frequency guard bands intrude on their frequency allocations.

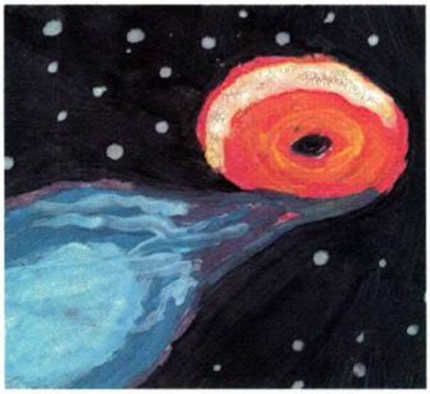
I drive more than 300 miles to escape light-polluted cities and find dark skies to photograph the stars. With more and more satellites, I worry that I will have to contend with space-satellite pollution, too. — *Dan Folz, Wheaton, Illinois*

At 10:50 p.m. on June 8, I stepped outside my home in rural Ontario to watch Mir pass overhead. I was delighted to see that the shuttle Discovery, which had been docked with Mir a few hours earlier, was still close — about 4° from Mir. What a wonderful sight to see these two brilliant points of light gliding majestically together across the sky.

I grew up during the decades of the Cold War. These were long years of suspicion and hate. Perhaps this vision of cooperation in space will be symbolic of a new era of hope and harmony as we head into the next millennium. — *Steve Irvine, Wiarton, Ontario, Canada*

Kids' Corner Comments

I need to make a correction regarding one of the winners of the painting contest for kids ages 12–16. I "won" second place for a painting of a black hole and a companion star featured on page 72 of the August issue. Actually, I did not paint it. Instead, I submitted the painting, as a surprise, for a friend who did paint it. Boy, was she surprised. My big mistake was using my name instead of hers. My friend Jennifer Nicole Rouvina, 13, from Auburn, Massachusetts, deserves the credit. — *Katherine McCarthy, Worcester, Massachusetts*



The powerful tug of a black hole creates a spinning accretion disk. Jennifer Rouvina

Earlier this year, as I read my January issue of *Astronomy*, I noticed the contests being held. The photography contest for ages 12–16 caught my eye. I've been interested in astronomy since 1993 and I have been a CCD photographer since 1997. I wanted to see how my photographs would compare to those taken by others in my age group, so I sent in a few photos and waited for the August issue that would announce the winners. I was shocked to win first place. Everyone I knew was impressed by my accomplishment. I could never have done it without help from the CCD list (ccd@wwa.com), the encouragement from my science teachers, Sue Bartow and Melissa Brown, and the love and support of my parents, Greg and Cindy. Thank you for helping to make my dream a reality. — *Jacob Thumberger, Hamilton, Ohio*

Mission Improbable

In "Interstellar Trekking" by Ken Croswell (June 1998), it appears that the author has fallen prey to a kind of faulty reasoning. He writes: "Those who believe that intelligent life is common in the cosmos would be forced to explain why none of that life has done the same and launched a mission toward one of the galaxy's most promising star systems: the sun."

It seems that stars similar to our sun would be promising for life presumably of a type similar to ours. However, it is easily conceivable that life on another planet might be totally different from life here, and life on such a planet might not require the conditions that exist here.

To other intelligent life forms, our sun might appear insignificant. Therefore, those life forms might not consider launching a mission to inspect the sun's planets for life. — *Lyndon Hardy, Dunedin, New Zealand*

Camera Exposure

Congratulations on 25 years from an amateur who's been with you from the beginning. I especially enjoyed Phil Harrington's "Film Noir, Pixel Perfect" (August 1998).

Unfortunately, Pentax recently stopped producing the fully mechanical K-1000. But there are still a few mechanical cameras available: Nikon's FM2 is one that is still available and it does not require batteries. Ricoh offers a simple, inexpensive, non-electronic single-lens-reflex camera, the most popular of which is the KR5 Super 2, and Olympus recently introduced no-frills mechanical cameras. In my experience all of these are as usable as the K-1000, and some include options not found on the Pentax.

Fuji is replacing some of its well-known print films beloved by astrophotographers. Gone is the outstanding Super G 800+. It was replaced by one of Fuji's new Superia films. — *Rodney Mollise, Mobile, Alabama*

Corrections

We incorrectly credited a photograph on page 75 of the July issue to Larry Landolfi. Photographer Ivan Dryer took that shot.

In the September issue, the story on the VLA credited Nancy Hendrickson for all the photos. Though Nancy took most of the photos that accompanied her story, Fred Espenak took the spectacular opening shot. A

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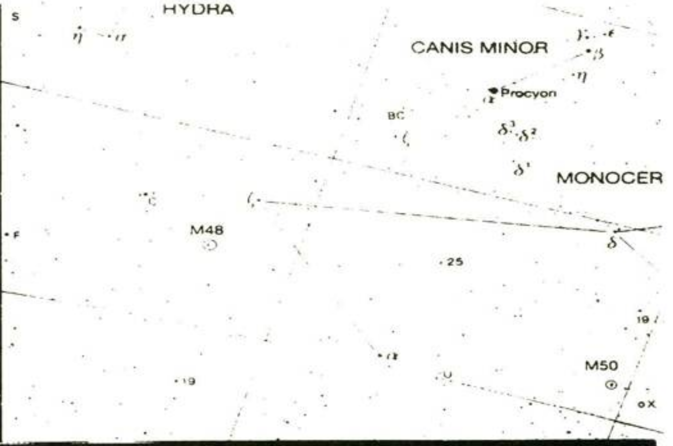

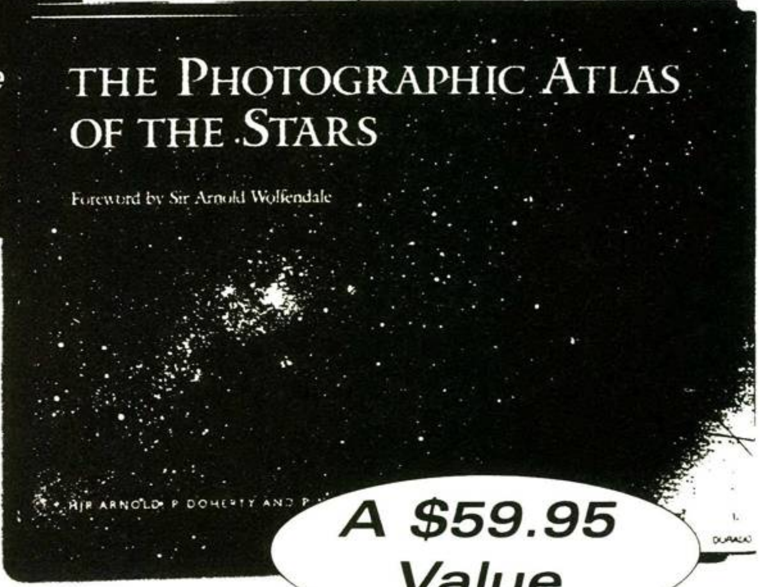
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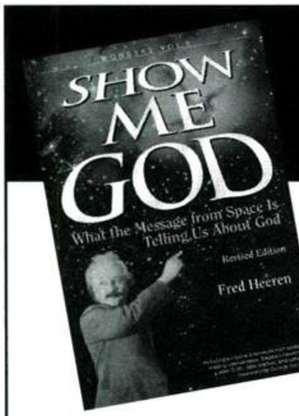

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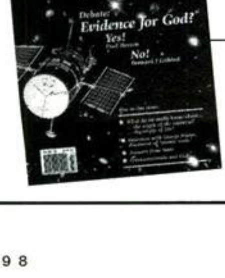

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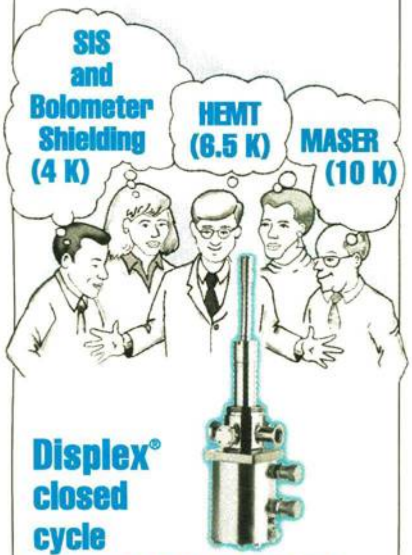
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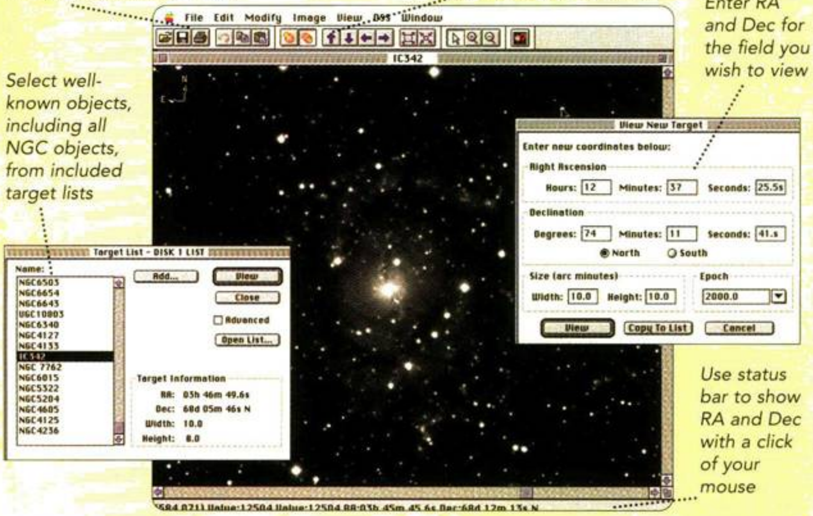

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NGC6015
NGC5322
NGC5204
NGC4605
NGC4125
NGC4236

Target Information
RA: 03h 46m 49.6s
Dec: 68d 05m 46s N
Width: 10.0
Height: 8.0

View New Target
Enter new coordinates below:
Right Ascension
Hours: 12 Minutes: 37 Seconds: 25.5s
Declination
Degrees: 74 Minutes: 11 Seconds: 41.s
● North ○ South
Size (arc minutes)
Width: 10.0 Height: 10.0
Epoch
2000.0

Print RealSky finding charts

Zoom in on any area

Enter RA and Dec for the field you wish to view

Select well-known objects, including all NGC objects, from included target lists

Use status bar to show RA and Dec with a click of your mouse

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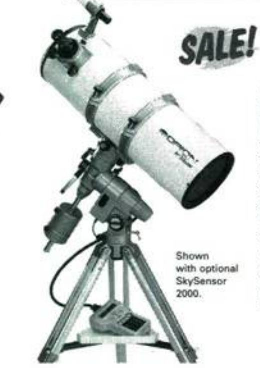

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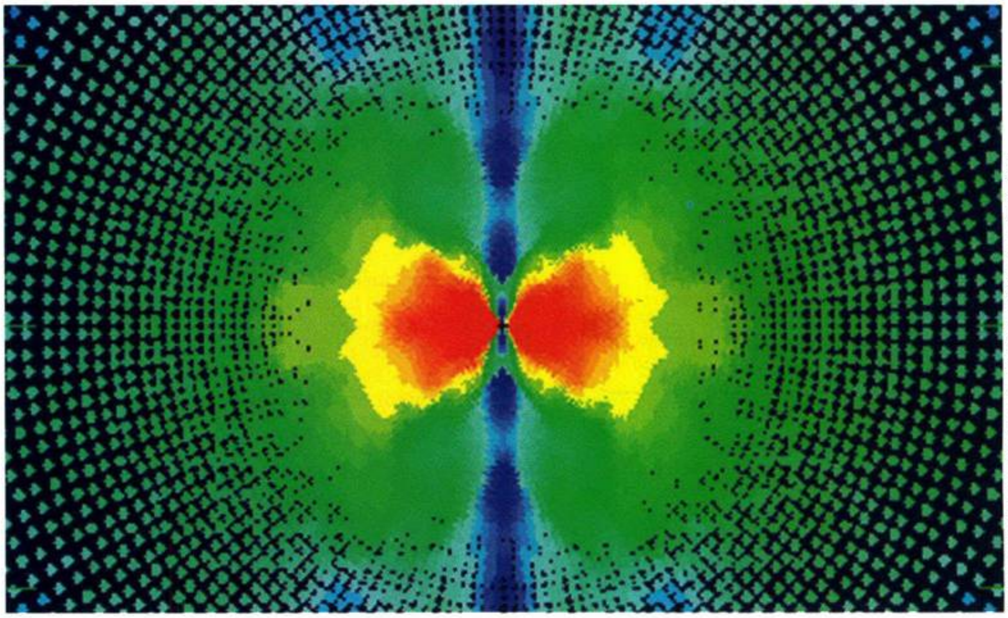
THE VIOLENT UNIVERSE

Souped-Up Supernova

Hypernovae May Spark Gamma-Ray Bursts

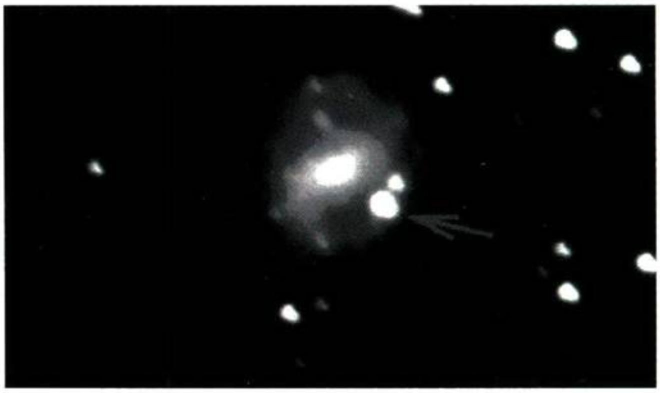


In this computer model, a rotating disk of gas (red) around a black hole channels ejected material into two thin jets (blue). The jets generate a gamma-ray burst when they slam into interstellar gas.

Andrew MacFadyen and Stan Woosley (University of California, Santa Cruz)

▶ Gamma-ray bursts have left astronomers scratching their heads ever since they were discovered by U.S. military satellites in the late 1960s. Part of the mystery was solved last year when astronomers found that these bursts emanate from galaxies billions of light-years away. But what exactly triggers these explosions, which can release 1,000 times more radiation than supernovae? A gamma-ray burst and a supernova recently flared from the same patch of sky, strongly suggesting that at least some gamma-ray bursts are triggered by stellar explosions. "This could be the missing link between supernovae and gamma-ray bursts," says astrophysicist Stan Woosley of the University of California, Santa Cruz.

On April 25, two satellites, BeppoSAX and the Compton Gamma Ray Observatory, detected the gamma-ray burst in the southern constellation Telescopium. On May 2, Dutch astronomers spotted Supernova 1998bw flaring in a spiral arm of a galaxy 120 million light-years away, in the same area as the April 25 burst. "The probability of a chance coincidence between the gamma-ray burst and Supernova 1998bw is well below one in ten thousand," says Princeton University astronomer Bohdan Paczynski.



The peculiar Supernova 1998bw (arrowed) flared from the same part of the sky and at about the same time as a gamma-ray burst, strongly suggesting the two events were one in the same.

Titus Galama (University of Amsterdam), et al., and ESO

Supernova 1998bw is perhaps the most peculiar supernova ever seen. Astronomers were startled by radio observations showing material racing outward at nearly the speed of light, suggesting an explosion much more powerful than most supernovae.

Perhaps this event was a "hypernova" — a term Paczynski coined in 1997 to describe stellar explosions 100 times more powerful than supernovae. While nobody knows exactly how a hypernova would work, Woosley has published a theoretical model in which a massive, rapidly rotating star collapses at the end of its life to form a black hole. The black hole voraciously accretes matter from a surrounding disk, powering twin, high-speed jets that slam into surrounding interstellar gas and generate a gamma-ray burst.

One potential stumbling block lies in the fact that the April 25 gamma-ray burst was about 10,000 times weaker than most gamma-ray bursts. Perhaps the jets were pointed away from Earth, meaning most of the gamma rays weren't beamed in our direction.

"One more case and everyone will agree that we have proof," says Paczynski.

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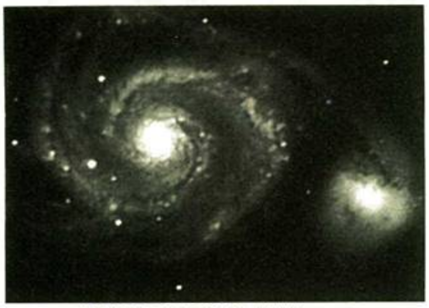

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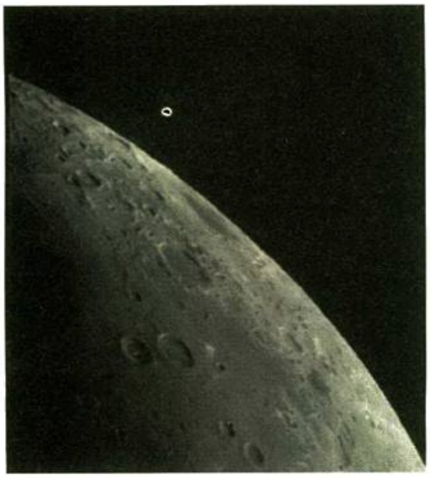

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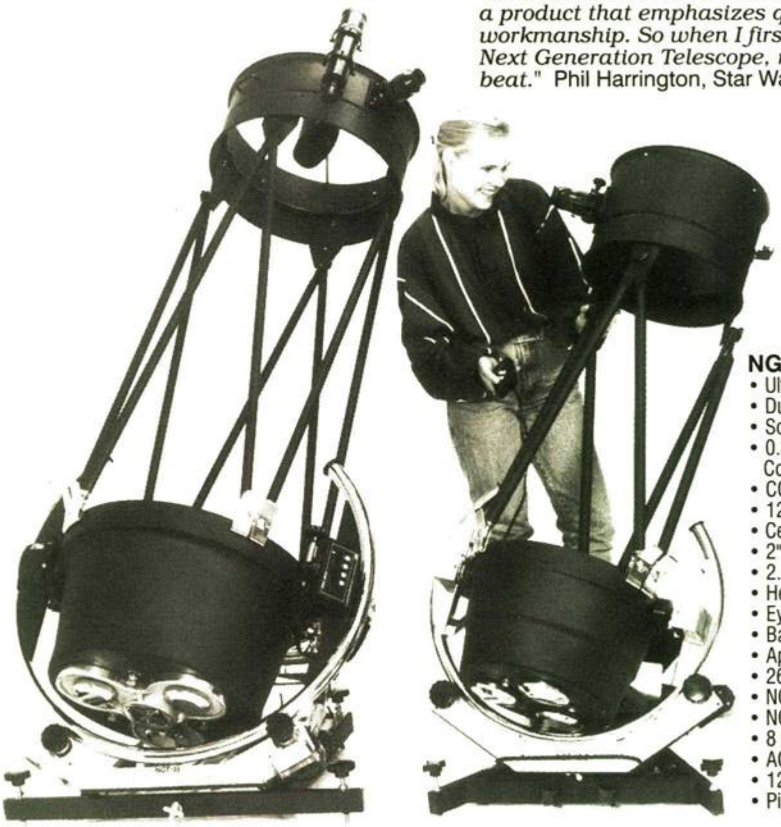

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NEUTRON STARS

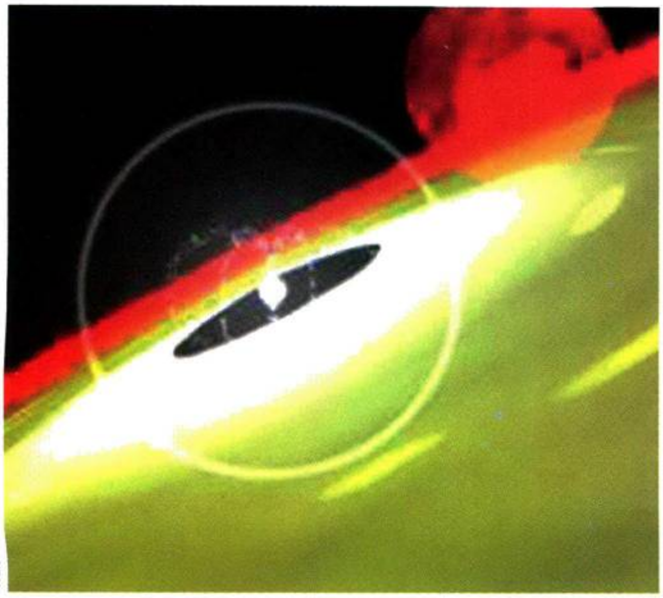
Pulsar Devours Doubt

A missing cosmic link has been found in a special kind of neutron star, called a millisecond pulsar. These dense, city-sized stars spin at blinding speeds, up to 1,000 times per second, much faster than normal pulsars. Millisecond pulsars emit weak radio waves, but the newly discovered pulsar SAX J1808.4-3658 is a different breed; it also gives off bursts of x rays. The first ever seen of its kind, this star confirms a theory described 15 years ago.

Pulsars begin their life in death. When a massive star dies, its core collapses and spins faster and faster as it shrinks. It emits pulses of x rays that pierce the cosmos like a signal from a galactic lighthouse. But even newborn pulsars shouldn't spin as fast as millisecond pulsars. The most popular theory says these objects evolve into millisecond pulsars by devouring material from a companion star. But until now, no one had observed this process.

"This is the first time one has been caught in the act," says Michiel van der Klis of the University of Amsterdam in the Netherlands. Van der Klis's team and a second team led by Deepto Chakrabarty of MIT

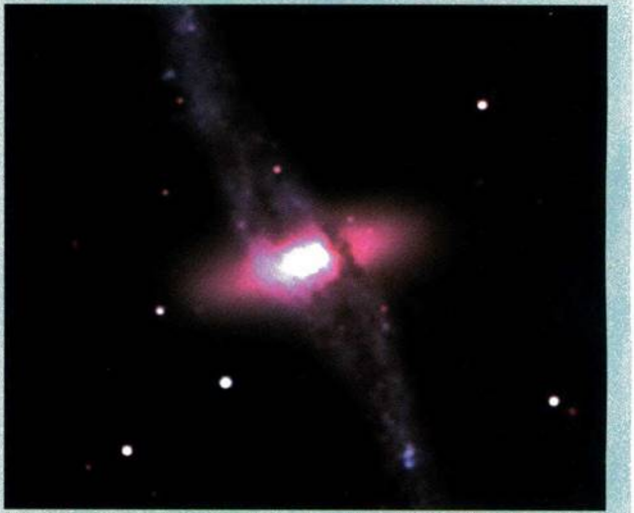
(see "Pulsars," p. 30)



In this illustration, a pulsar (white dot in foreground) draws matter from its companion (red star in background), forming a disk.

Walt Feimer (NASA/GSFC)

VERY LARGE TELESCOPE



RINGED GALAXY. Not too shabby for a picture "obtained under mediocre viewing conditions," eh? The image, taken with the European Southern Observatory's 8.2-meter Very Large Telescope (VLT) in Chile during its ongoing commissioning phase, shows the peculiar galaxy NGC 4650A in Centaurus, about 165 million light-years away. The galaxy is actually two galaxies in one: a pinkish lenticular (type S0) galaxy consisting of mainly old stars and a ring of gas, dust, and mostly young stars that might be the remnant of a galactic merger. European Southern Observatory

AURORAE

Awakening the Northern Lights

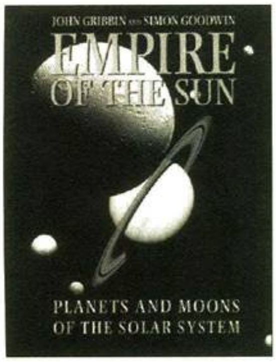
Everybody loves aurorae — the curtains of red and green light that waver magically in nighttime skies. Observations dating back more than 200 years indicate that aurorae occur most frequently during peak periods of activity in the 11-year solar cycle, called solar maxima. But new research from space physicist Patrick Newell and his colleagues at Johns Hopkins University shows that those studies were wrong.

Using particle detector data from the U.S. Air Force Defense Meteorological Satellite Program, Newell's team found that the frequency of aurorae easily visible to the naked eye stays more or less constant throughout the solar cycle. In fact, under sunlit conditions fewer aurorae occur as solar activity increases. Only huge aurorae, which reach middle latitudes, are more common just after solar maximum — but these events are extremely rare.

To explain their results, Newell and his colleagues report in the May 28 *Nature* that the frequency of aurorae is tied to the electrical conductivity of the upper atmosphere (the ionosphere). Auroral activity is

(see "Northern Lights," p. 30)

EMPIRE OF THE SUN
PLANETS AND MOONS
OF THE SOLAR SYSTEM
John Gribbin and Simon Goodwin



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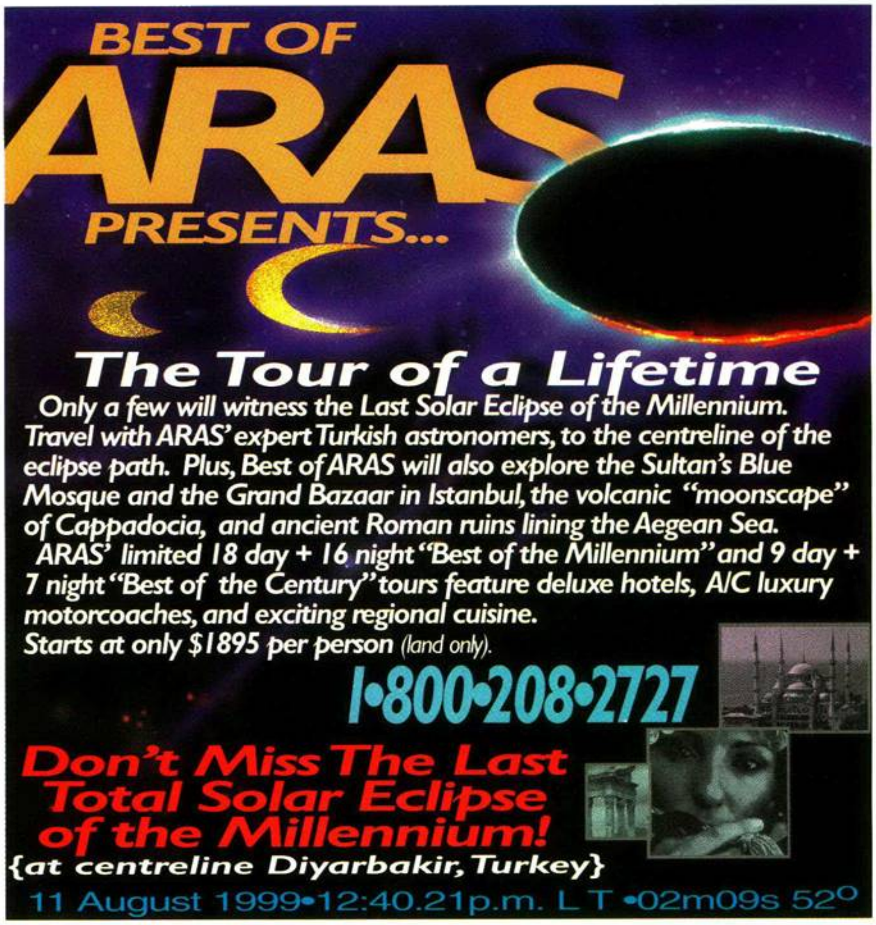

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(Pulsars)
discovered the pulsar using NASA's Rossi X-ray Timing Explorer spacecraft, and published their findings in the July 23 *Nature*. Van der Klis's team calculated that the pulsar spins more than 400 times per second. Chakrabarty's team found subtle two-hour modulations in the pulse, meaning the pulsar is orbiting a companion star every two hours.

The fact that the millisecond pulsar is emitting x rays is another clue that it is feeding. As the pulsar's strong gravitational pull sucks gas from its companion, the gas heats up and emits x rays. The gas spirals inward, contacting the pulsar's surface at an angle and accelerating its spin. Eventually the pulsar will lick its plate clean. At that point, it will begin to slow down and emit only radio waves.

METEORITES

New Mexico's Sky Is Falling

▶ On Saturday, June 13, at approximately 7:32 a.m. local time, a brilliant fireball exploded just south of Portales, New Mexico. This fireball was first sighted by rancher Ronnie Johnson near Happy, Texas. The fiery trail was visible for about eight seconds. By remarkable coincidence, the end point of the fireball passed almost directly

(see "New Mexico Sky," p. 32)

This 37-pound meteorite landed near Portales, New Mexico. Hal Povenmire

(Northern Lights)
at its lowest when ionospheric conductivity is high, as occurs at solar maximum. As the sun's ultraviolet output increases at solar maximum, the ultraviolet rays break apart atoms in the ionosphere, and the resulting free electrons make the ionosphere electrically conductive. The electrons can easily flow back and forth between the ionosphere and outer space, and this stable situation means aurorae are few and far between.

R.B. Slobins

New studies suggest that aurorae are electrical discharges similar to lightning.

"Aurorae behave very much like a fluorescent bulb," says Newell. "The discharge process that emits light only works when there is no alternate conducting path. If a conducting path, like a copper wire, exists in a fluorescent bulb, it won't emit light. But with no conductivity, some of the electrons separate from atoms and get accelerated. When those electrons hit other atoms, they give off light, and this is what happens in the ionosphere when aurorae are generated." Newell and his colleagues liken aurorae to another discharge process: lightning.

The conductivity model explains why the frequency of aurorae stays the same at nighttime: There are no solar ultraviolet rays hitting the ionosphere to increase conduction. Newell says the research is good news for the public. "If you're interested in seeing aurorae, you won't do any better waiting two years for the next solar maximum."

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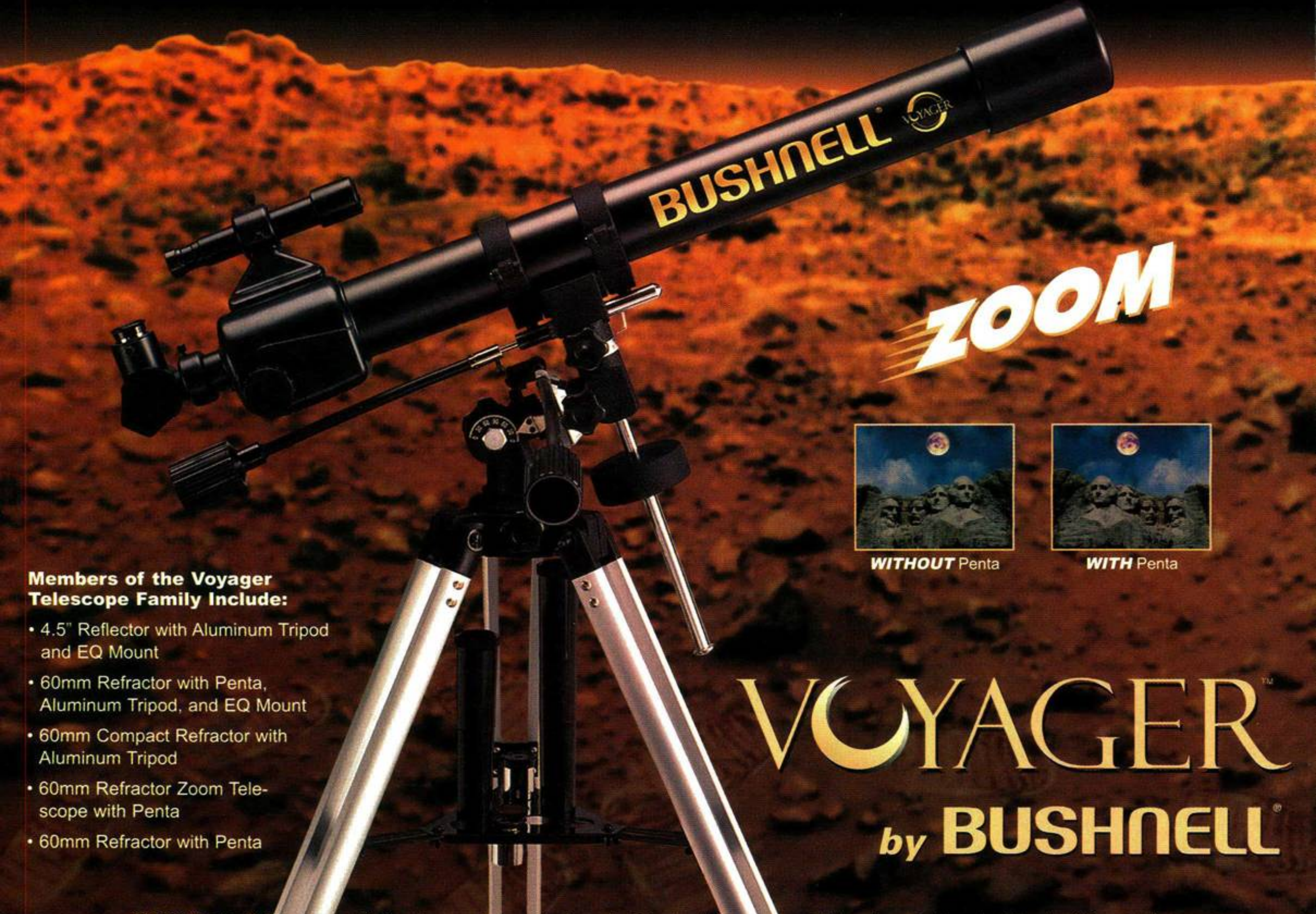

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(New Mexico Sky) over the house of veteran meteorite hunter Ivan "Skip" Wilson.

Wilson heard two sonic booms followed by six to eight popping sounds. When he stepped outdoors, he saw a gray, corkscrew-shaped dust trail. He thought it could be a fireball, but he was uncertain because he also heard a jet airplane. What he didn't know was that his neighbor, Nelda Wallace, heard a whistling sound just as she sat down to drink her morning coffee. A 37-pound meteorite had just fallen in her backyard 70 yards away.

The meteorite was half buried in the dry, hard soil. The black fusion crust was easily visible and it was far too hot to handle. Even closer to Wilson, Gale Newberry walked into his barn and saw daylight shining through a hole in the roof and a gash in the wall. Newberry found a one-pound meteorite lodged in the wall. Soon, a 39-pound meteorite had been recovered from the field of Elton Brown. To date, 38 meteorite pieces weighing a total of 143 pounds have been recovered, but the total is estimated to be at least 250 pounds.

The fall consists of stony, stony-iron, and iron meteorites. Previous falls have included meteorites of two types, but this is thought to be the only event including all three classes. Oddly, several fragments of the meteorite show unusually thick metallic veins. — **Hal Povenmire**

OBITUARY

Alan B. Shepard

(1923 — 1998)

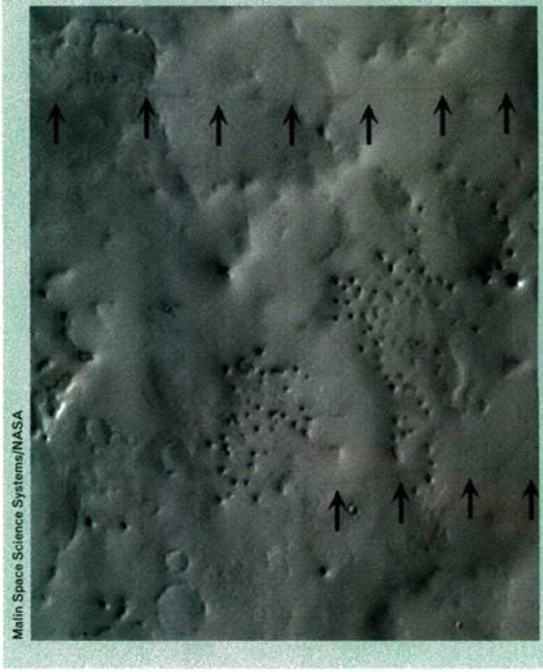
▶ On May 5, 1961, Alan B. Shepard, Jr. rode into the annals of history atop a Redstone rocket. His Mercury 7 flight lasted only 15 minutes, but by attaining an altitude of 116 miles, Shepard became the first American to reach outer space.

Shepard died in Monterey, California, on July 21 following a long bout with leukemia. He was 74.

Shepard's flight boosted sagging American morale following Soviet cosmonaut Yuri Gagarin's 108-minute, single-orbit flight on April 12, 1961.

(see "Shepard," p. 34)

MARS GLOBAL SURVEYOR



Malin Space Science Systems/NASA

DUST DEVIL TRACKS. Scientists analyzing this image from Mars Global Surveyor noticed two thin, dark lines (arrowed) stretching for several miles across the sandy plains of Mars. Since we don't know of any martian dune buggies, the lines, which are only 50 feet (15 meters) across at their widest, were almost certainly etched by dust devils. This comes as no great surprise: Mars Pathfinder imaged several dust devils rolling across the surface of Mars (see "Martian Dust Devils Imaged," October 1998 AstroNews).

ASTEROIDS

Blindsiding Earth

▶ If the threat of asteroid impacts can be likened to a game of Russian roulette, another bullet has been added to the chamber. University of Hawaii planetary astronomers David Tholen and Robert Whiteley have discovered what appears to be the first of a new class of threatening asteroid — whose members orbit the sun inside Earth's orbit.

"These asteroids could pose a relatively large threat to Earth because they are hard to find," says Tholen, who took the discovery image with a specialized CCD camera coupled to a 2.2-meter telescope on Mauna Kea. Asteroids closer to the sun than Earth will always appear near the sun in the sky, so they can only be seen near the horizon just before sunrise or just after sunset. Because these asteroids are so difficult to detect, astronomers haven't spent much time and effort looking for them.

Tholen and Whiteley only observed the asteroid, designated 1998 DK$_{36}$, on two nights in February. The two observations weren't enough to allow them to pin down the orbit to high accuracy, so Tholen says there's a slight chance that the asteroid's trajectory could carry it beyond Earth's orbit. Based on its brightness, Tholen and Whiteley estimate 1998 DK$_{36}$ to be about 130 feet (40 meters) across, slightly smaller than the asteroid that flattened 700 square miles of Siberian forest in 1908.

The asteroid probably formed in the main belt between Mars and Jupiter and later migrated to the inner solar system following gravitational perturbations by Jupiter and other planets.

(see "Blindsiding," p. 34)

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(Shepard)

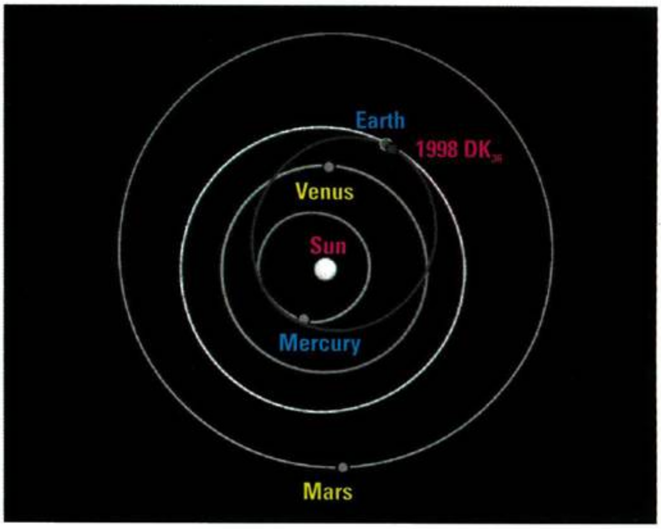
More important, Shepard's giant step set the stage for the spectacular NASA triumphs that would follow. Spurred by the success of Mercury 7, President John F. Kennedy declared before Congress just three weeks later: "I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth."

Besides being the first American in space, Shepard is one of only 12 people to set foot on the moon. He commanded the 1971 Apollo 14 mission, which got the Apollo program back on track following the near-disaster of Apollo 13. In their two excursions on the lunar surface, Shepard and fellow Apollo 14 moonwalker Edgar Mitchell set up a science station and collected 92 pounds (42 kilograms) of moon rocks. Perhaps Shepard's most celebrated act on the moon was driving two golf balls with a makeshift club. The first landed in a nearby crater, the second, in Shepard's words, traveled "miles and miles and miles."

"Alan Shepard will be remembered, always, for being one of the original Mercury astronauts, for being the first American to fly in space, and for being one of only 12 Americans ever to step on the moon," says NASA Administrator Daniel Goldin. "He should also be remembered as someone who, even in his final days, never lost sight of the future."

As commander of Apollo 14, Alan Shepard became the fifth man to walk on the moon. NASA/JSC

APOLLO 14
Shepard
Roosa



David Tholen and Robert Whiteley (University of Hawaii)

Calculations of 1998 DK$_{36}$'s orbit suggest that it always stays inside Earth's orbit — the first such asteroid ever seen.

(Blindsiding)

Similar perturbations could have redirected many more asteroids into the inner solar system. While Tholen's calculations show that 1998 DK$_{36}$ never comes closer than 750,000 miles from Earth's orbit, the ones whose orbits intersect Earth's orbit could sneak up and blindside Earth from the daytime hemisphere without us ever knowing they were approaching. "This asteroid is nothing to lose sleep over," says Tholen. "It's the ones we haven't found yet that are of concern."

In July astronomers found three more "potentially hazardous asteroids" in more typical orbits, raising the total to 128. To coordinate the various efforts to find Earth-approaching asteroids, NASA recently established a program office at the Jet Propulsion Laboratory under the direction of Donald Yeomans. The goal of the program, says Yeomans, is to locate within the next decade 90 percent of the estimated 2,000 asteroids that could cause global disaster.

ORIGIN OF LIFE

Cosmic Solution for Biological Mystery

► Astronomers have found an unusual form of starlight that could explain why life's basic molecules have certain shapes. This light may have seeded our young solar system with the building blocks of life, which then pelted Earth in a rain of comets, meteorites, and space dust.

The proteins in our bodies, which perform vital tasks in our cells, are made of chains of amino acids. Each amino acid can have one of two mirror-image shapes, called left-handed and right-handed. All terrestrial life, however, uses only the left-handed (L) variety. Biologists don't know whether this pattern, known as homochirality, was in place before life began or

(see "Cosmic Solution," p. 36)

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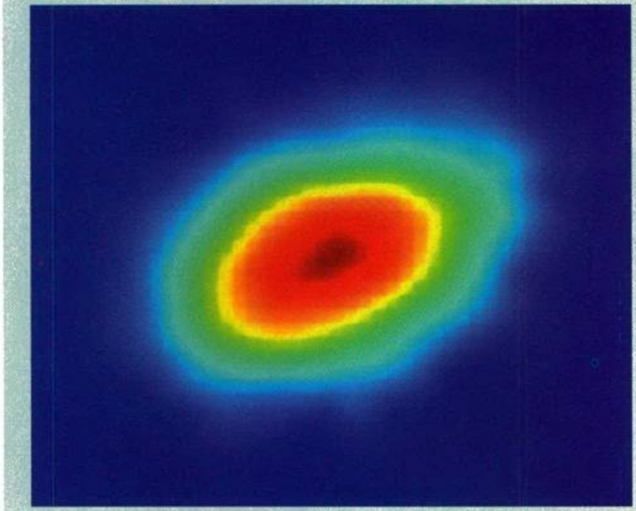
(Cosmic Solution) was created by the first organisms.

In the July 31 *Science*, an international team of astronomers led by Jeremy Bailey of the Anglo-Australian Observatory argues for a space-based origin. The researchers spotted a type of radiation flowing from a cloud in the Orion Nebula where stars — and perhaps amino acids — are forming. The radiation, called "circularly polarized light," spirals steadily as it streams toward Earth. A special camera saw low-energy infrared light of this type, but Bailey's group calculates that high-energy ultraviolet light scattered from dust in the nebula should become circularly polarized as well.

Depending on its direction of spin, high-energy ultraviolet light could leave behind L amino acids by destroying most of the mirror-image molecules, says Bailey. The heavy

(see "Cosmic Solution," p. 38)

PROTOPLANETARY DISKS



MASSIVE STAR HAS DISK. Astronomers have found all sorts of disks around young stars (see "Spying on Planetary Nurseries," page 62), but for the first time they have imaged a disk around a massive young star. The disk orbits a star known as G339.88–1.26, which has about 20 times the mass of the sun. The disk, seen in this infrared image taken by the 3.6-meter telescope at the European Southern Observatory in Chile, is about 500 times the size of the solar system. Even though the star is 10,000 times more luminous than the sun, it can't be seen because most of its energy output lies in the ultraviolet part of the spectrum; dust particles in the disk absorb ultraviolet light and reradiate the energy in infrared light. While the image proves that disks can survive the harsh conditions around a massive star, astronomers don't know if planets will ever form inside the disk. European Southern Observatory

SOHO Phones Home

On August 3, the Solar and Heliospheric Observatory (SOHO) answered radio signals sent by ground controllers from a Deep Space Network antenna in Australia. Later transmissions included temperature and electrical data. "This is the best news I've heard since we lost contact with SOHO," said Roger Bonnet, the European Space Agency's Director of Science. "We should just hope that the damage sustained by SOHO's enforced period of deep freeze does not affect the scientific payload too much." Ground controllers lost contact with the $1 billion spacecraft on June 24 (see "SOHO, Phone Home," October AstroNews). For up-to-date information, go to http://sohowww.nascom.nasa.gov/.

Kitty Hawk Flies Mars

The planned 300-pound (135 kilograms) Mars Airborne Geophysical Explorer has a wingspan of 32 feet (9.75 meters). MSSS/NASA-Ames/NRL/OSC

Four organizations have teamed up to propose a Discovery-class mission to fly a robotic airplane over Valles Marineris, a system of canyons that stretches across nearly 3,000 miles of Mars. If selected by NASA, the $246-million mission would launch in May 2003 and arrive on December 17 — just in time to coincide with the 100th anniversary of the Wright Brothers' historic flight. The instrument- and camera-laden airplane, tentatively named the Kitty Hawk, would separate from its entry vehicle at an altitude of 1.2 miles (2 kilometers) and then soar over the canyons for three hours before running out of power. For more details, see http://www.msss.com/mage_release/index.html.

A Meteor Shower Revival

June is not the peak of the meteor observing season, so imagine the surprise of observers in Japan when they saw up to 100 or more meteors per hour on the night of June 27/28. Radar observations of the brief shower pinpointed its radiant in Bootes and showed that the meteoroids seemed to follow orbits similar to that of the periodic Comet Pons-Winnecke. Rather than a new shower, this is probably a revival of the recently dormant June Bootid meteor shower. The June Bootids were active early in the 20th century and put on good displays in 1916, 1921, and 1927. For the past several decades, however, rates had sunk to an almost negligible one or two per hour. Whether this year's show marks a permanent revival or just a one-time recurrence, you can bet observers will be out in force next June.

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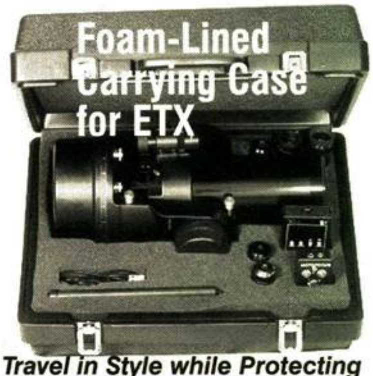

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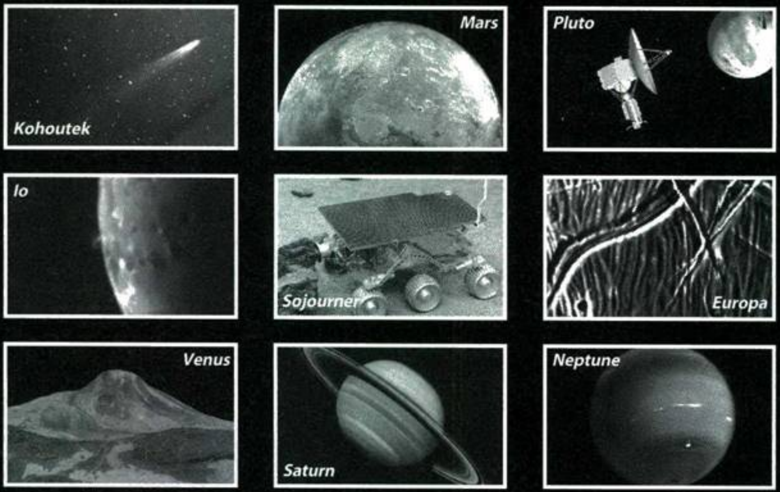

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(Cosmic Solution)

debris in our solar system, he proposes, could have swept up the amino acids and delivered them to Earth. Organic geochemist John Cronin of Arizona State University recently found evidence that this process still happens today: Meteorites that struck Australia and Kentucky this century both contained a few percent more L amino acids than the right-handed variety.

Some biochemists think Bailey's scenario has too many unlikely twists. University of California, San Diego origin-of-life expert Stanley Miller says chemical reactions on Earth probably neutralized any surplus of L amino acids before life could use them. "I've always felt that homochirality arises by chance," he says. — **ROBERT IRION**

MASS EXTINCTIONS

Muon This

▶Most people accept that an asteroid caused the last great mass extinction. But astrophysicist Arnon Dar and his colleagues at the Technion-Israel Institute of Technology blame a different extraterrestrial phenomenon. Streams of electronlike particles (called muons) and radiation released when neutron stars collide, they say, bombarded Earth's atmosphere. The muons destroyed the ozone layer and produced great amounts of radioactivity.

The theory, published in the June 29 *Physical Review Letters*, could explain many past events of extinction and recovery. According to the astrophysicists, the radioactivity and muons would kill most ground life. The muons would penetrate the deep underground and seas, exterminating life there as well. Muons and radiation could have then spurred rapid mutations among the living, resulting in new species. Chemical elements in rocks will be scrutinized for traces of energetic particles to support the claim.

WEBSITE

Check *Astronomy*'s website for news as it happens — http://www.astronomy.com.

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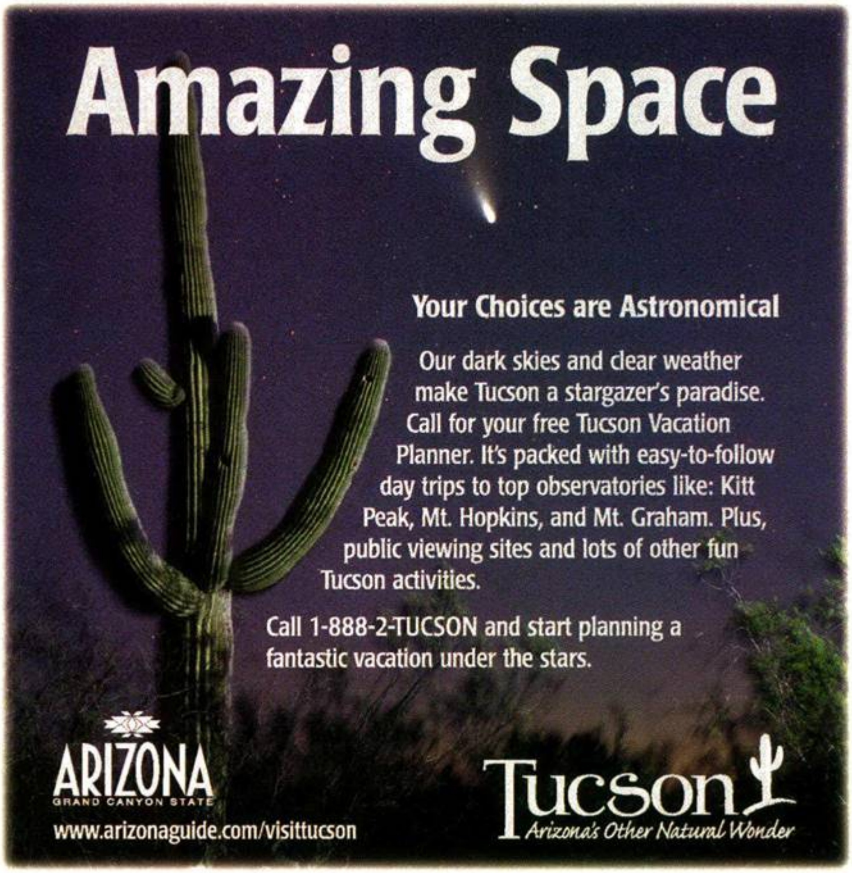

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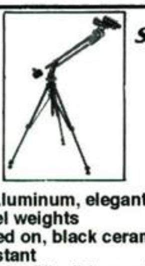

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LOOK

THE A LIST:

Over the past 25 years, these greatest deep-sky objects have come to be the most treasured sights beyond the solar system.

- *The gas in the Orion Nebula (M42), which spans 30 light-years, has a density less than a millionth that of a laboratory vacuum, yet this star factory will make more than 10,000 stars like the sun.*

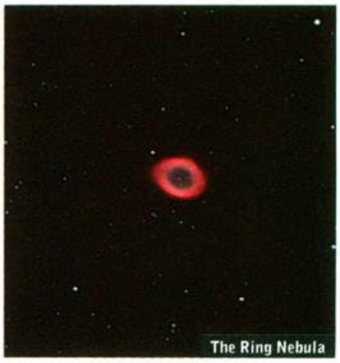
- *At magnitude 3.1, Cancer's Beehive Cluster (M44) is so bright that it was used in ancient times as a weather indicator. If the cluster was visible, the skies would remain clear, but a slight haze, suggesting incoming rain, would render the cluster invisible. In 130 B.C., astronomer Hipparchus called it the "little cloud."*

The Orion Nebula

Tony and Daphne Hallas

- *Neighbors by chance, the two star groups that form the Double Cluster in Perseus (NGC 869 and NGC 884) are physically unrelated and lie at distances of 7,175 and 7,500 light-years.*

- *The Whirlpool Galaxy (M51) in Canes Venatici constitutes the brightest pair of interacting galaxies in the sky. The smaller galaxy (NGC 5195) appears to be attached to an arm of the larger one (NGC 5194); they are simply strangers passing in the night.*


The Ring Nebula

Bob and Janice Fera

- *The bright form of the Omega Nebula (M17) in Sagittarius stretches 12 light-years across, three times the distance from the sun to the nearest star, Alpha Centauri.*

- *The sky's most observed planetary nebula, the Ring Nebula (M57) in Lyra, is not a ring at all. It is a tube of gas seen end-on, which makes it appear ring-like.*

- *Notoriously challenging for visual observers, the Horsehead Nebula (B33) in Orion consists of carbonaceous dust grains no larger than the tiny particles that comprise cigarette smoke.*

- *The Lagoon Nebula (M8) in Sagittarius contains dozens of Bok globules, tiny dark knots of dust. These dark bubbles conceal protostars that are rapidly coalescing into baby suns.*

- *The Coma Berenices Star Cluster (Melotte 111), the third closest star cluster to us, holds 80 stars at a distance of 260 light-years. The result is a rich field 4½° across, perfect for binocular observing, featuring some stars shining more than 50 times brighter than the sun.*

- *The Andromeda Galaxy (M31), the closest spiral galaxy outside the Milky Way, lies 2.2 million light-years away. For the majority of observers it is the most distant object visible to the unaided human eye.*

- *The Crab Nebula (M1) in Taurus, the nearest young supernova remnant, is the remains of a supernova explosion that occurred in A.D. 1054. The Hubble Space Telescope has detected changes in the nebula's shape over time periods as short as one week.*

- *The Pinwheel Galaxy (M33) in Triangulum, third primary member*

The Andromeda Galaxy

Jack Newton

BACK

HOT DISTANT SIGHTS

of the Local Group of galaxies (after Andromeda and the Milky Way), can be spotted by some keen-eyed observers without optical aid on very dark nights. It lies 3.6 million light-years away.

- Arguably the most spectacular star cluster in the sky, the Pleiades (M45) in Taurus blends 100 bright young stars with the faint, wispy remains of bluish reflection nebulosity. The cluster's dipper shape makes it stand out easily.

Omega Centauri

Joe Liddell

- The Coal Sack is the most noticeable dark nebula in the sky. Located in the southern constellation Crux, it was recorded by Portuguese navigators as early as the 16th century. Nearby lies the brilliant little gem of a star cluster called the Jewel Box.

- With its shape often described as an apple core or butterfly, the Dumbbell Nebula (M27) in Vulpecula is one of the greatest telescopic planetaries in the sky. Modest telescopes reveal the 13th-magnitude central star, the white-hot remnant that blew off its outer layers, creating the beautiful glowing gas cloud.

The Large Magellanic Cloud

Luke Dodd

- Omega Centauri (NGC 5139), the largest and brightest globular cluster in the sky, appears like a 4th-magnitude star to the eye alone. Its massive sphere holds more than a million aged stars but probably few planets in orbit around them.

- The Large and Small Magellanic Clouds, irregular galaxies, orbit the Milky Way in lazy ovals. Visible from the Southern Hemisphere, they will eventually be shredded by the gravitational tug of the Milky Way. In 1987 a brilliant supernova flared in the Large Cloud.

- Whereas the Crab Nebula resulted from a supernova a mere 944 years ago, the Veil Nebula (NGC 6960, NGC 6992–5) in Cygnus represents the remains of a star that violently exploded 150,000 years ago. The delicate, rope-like filaments of glowing gas can be seen in a 6-inch telescope.

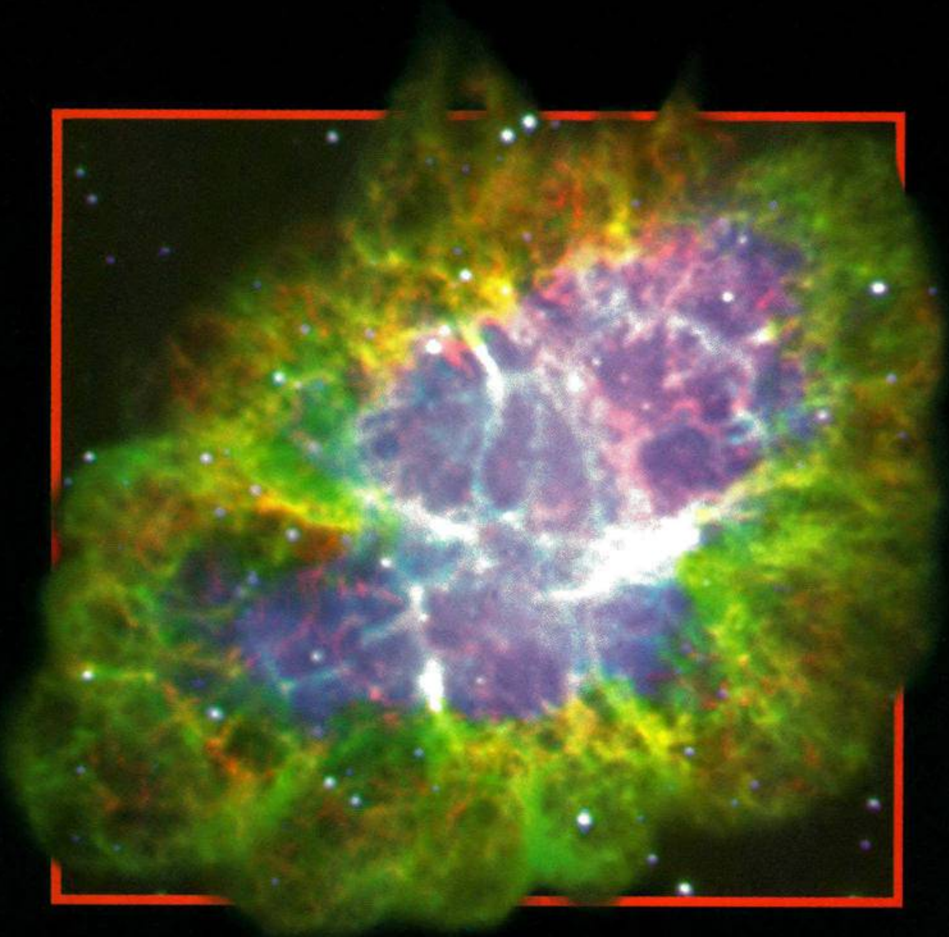
- Immortalized in the Hubble Space Telescope's most published picture, the Eagle Nebula (M16) in Serpens features towering pillars of dust backlit by a broad expanse of reddish, glowing gas. The star cluster forming from this rich complex of nebulosity holds at least two dozen furiously energetic O and B stars.

- Open cluster M7 in Scorpius has been orbiting the galaxy as a group for 220 million years. Its 80 sparkling stars scattered across an enormous field of 80' — nearly three full moons stacked end to end — make it one of the most easily visible star clusters to the naked eye.

- Revered by Northern Hemisphere viewers, the Hercules Cluster (M13) is perhaps the prototypical globular star cluster.

The Pleiades

Bill Iburg

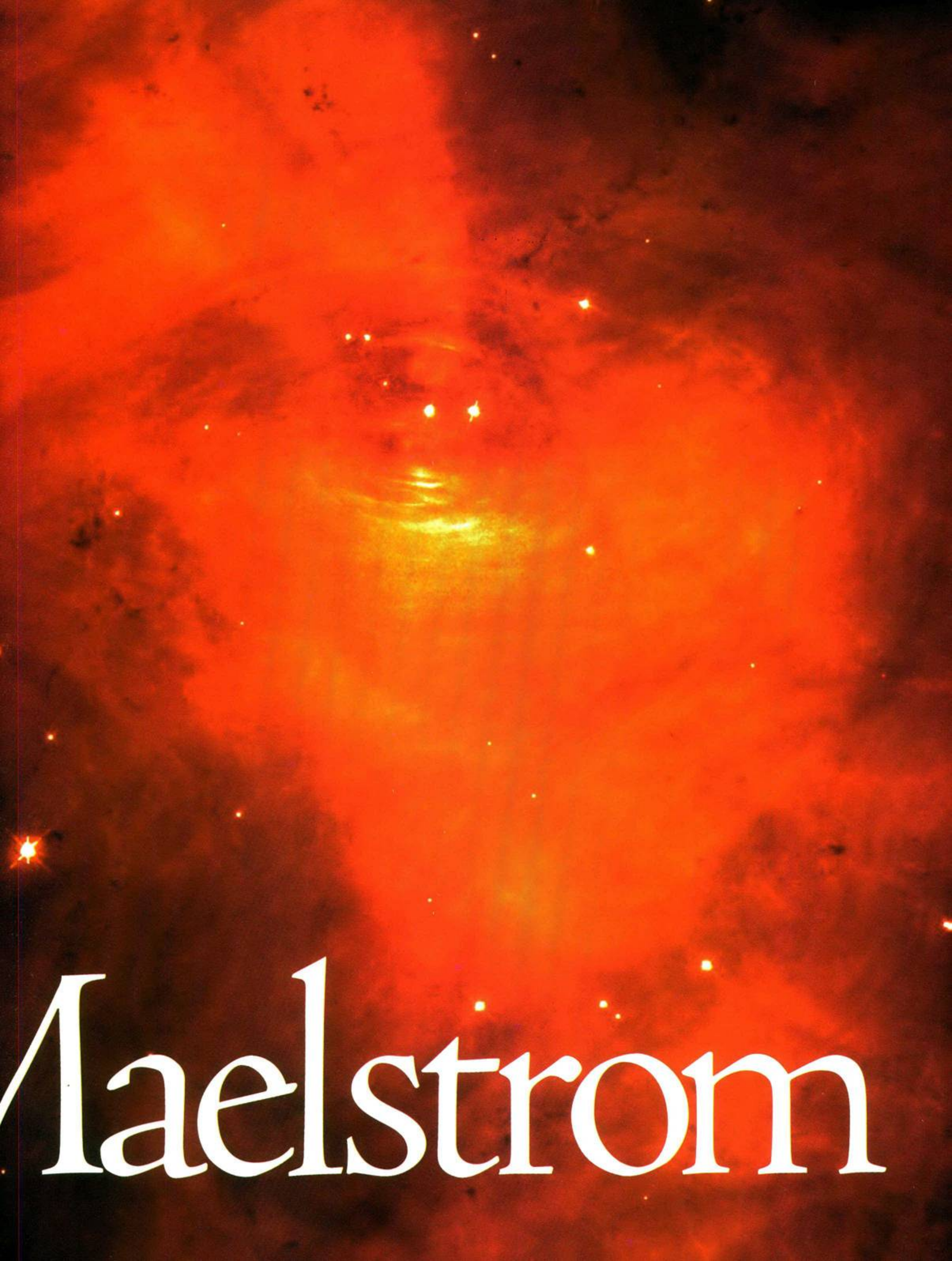


Nearly a thousand years after its birth, the Crab Nebula still glows with the fury of a newborn.

by Robert Zimmerman

Into the M

Both images: Jeff Hester and Paul Scowen (Arizona State University) and NASA



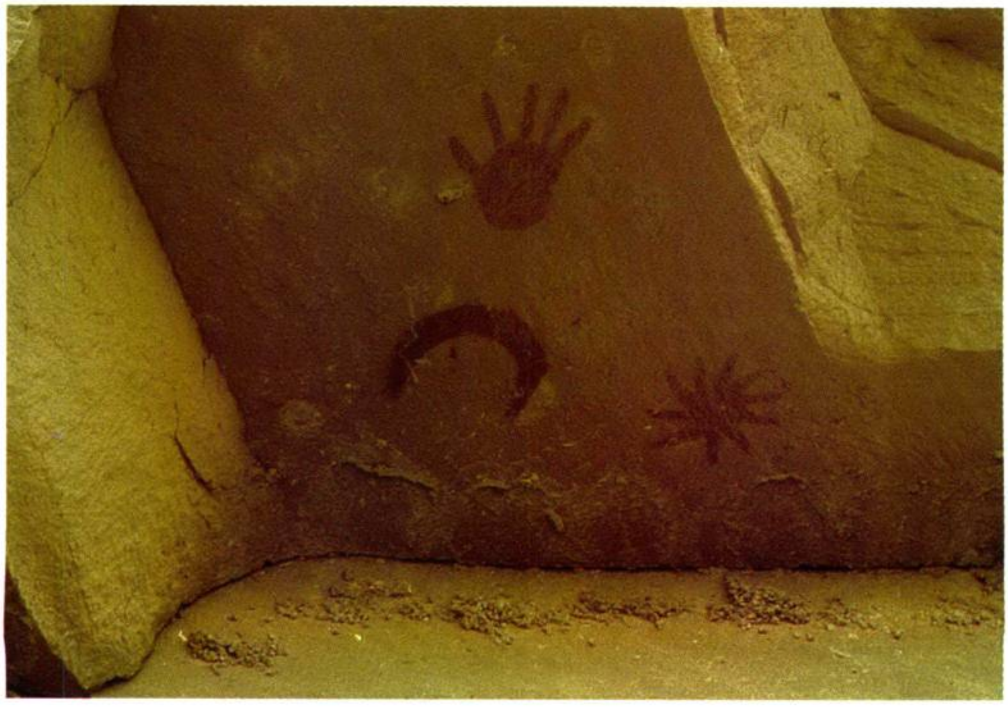
Maelstrom

THOUGH THE SUPERNOVA EXPLOSION took place almost a thousand years ago, the aftermath still rages. Vast clouds of gas and dust, flung from the eruption, arch outward into arcs and jets that extend for light-years. Amid the debris of this exploded star pulse powerful waves of electromagnetic energy, racing along flux tubes larger than entire solar systems.

In the center of this maelstrom sits a superdense ball of neutrons about ten miles across, the size of the eye of a typical hurricane. Once, this tiny orb was a majestic sun of great color and beauty, outshining the stars around it for thousands of light-years. Now its nuclear fires have died, leaving behind the slowly fading ashes of a stellar corpse.

And yet, what an active and dangerous corpse it is. The carcass, one and a half times heavier than the sun, is squeezed into such a small volume that a handful of its "soil" would weigh several million tons. Spinning madly at a rate of thirty times per second, it throws out charged particles in such violent gusts that the radio signal it emits is one of the strongest in our sky, even though it lies more than 6,000 light-years away. Intense x-ray and gamma radiation would instantly kill any human foolish enough to venture closer than a dozen or so light-years. As these immense waves of electromagnetic energy roll outward, they act almost like garden rakes, shaping and twisting the huge debris cloud into the delicate filaments and knots we see from Earth.

This is the Crab Nebula, a colossal, high-energy laboratory in space and one of the brightest, nearest, and most recently formed supernova remnants. And while astronomers have been passionately studying the Crab for more than 150 years, they have only recently discovered just how violent it is. As Jeff Hester of Arizona State University noted in 1996, "The Crab is so dynamic that if you wait more than about a week to take your next look, you're going to get the wrong impression because things have changed so terribly much."



On July 4, 1054, an object brighter than the brightest star appeared near the crescent moon. Anasazi skywatchers in Chaco Canyon (now in New Mexico) likely saw this supernova and recorded it in this petroglyph.

Ron Lussier

Exploding into View

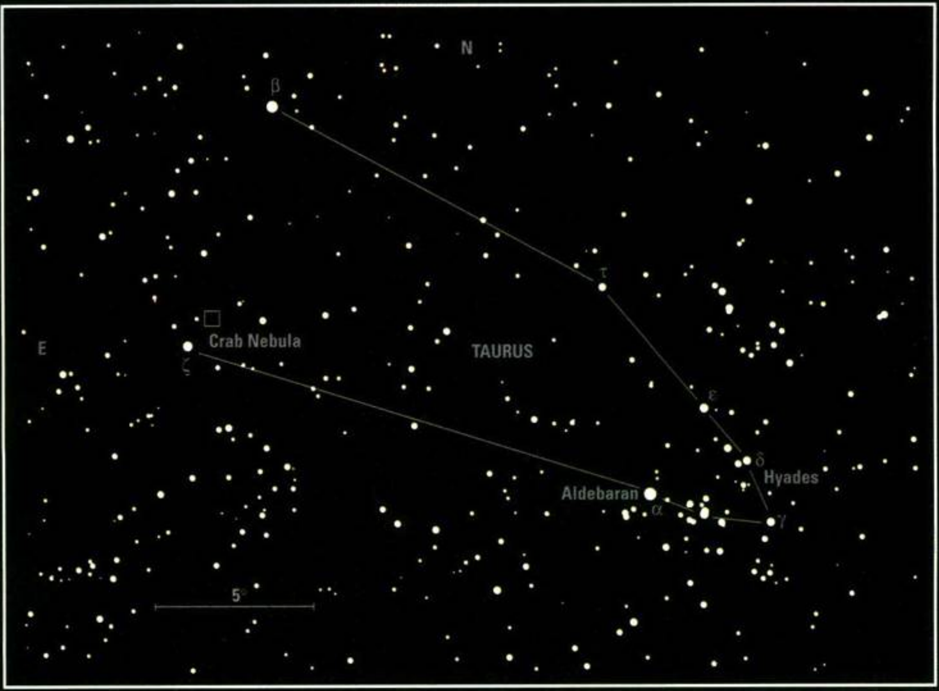
On the night of July 4, 1054, Chinese astronomers first noted the appearance of a brilliant beacon in the constellation Taurus the Bull. We now know that this "guest star" marked both the cataclysmic death knell of a supergiant star and the birth pangs of the Crab Nebula. But the nebula remained entirely unknown until John Bevis, an English doctor and amateur astronomer, first glimpsed it with his telescope in 1731. Seventeen years later, the French comet hunter Charles Messier rediscovered it independently. Because the "nebula had such a resemblance to a comet" in the primitive telescopes of the time, Messier decided to compile a list of similar objects so that future comet hunters "would not confuse these same nebulae with comets just beginning to shine." The result was Messier's famous catalog, in which this object was designated M1. When the Third Earl of Rosse noted in 1844 that the nebula reminded him of a crab, the name stuck.

For the next hundred years astronomers struggled to learn the Crab's origin. They closely monitored the nebula and saw significant changes in its appearance over periods of less than a decade. By the 1920s they were able to measure its expansion rate and deduced that the nebula had been expanding for approximately 900 years. This information, coupled with the nebula's proximity in the sky to the supernova of 1054, indicated that the two events were probably linked.

In 1942, the radio source at the Crab's center was discovered, and in 1954, astronomers confirmed that the luminescence of the central white cloud was polarized, proving that this cloud was energized by a powerful magnetic field. Then, in 1968, astronomers taking high-speed photos of a dim star at the center of the Crab showed it to be winking on and off thirty times a second. This was the first visible-light identification of a recently discovered class of objects known as pulsars. Theorists quickly recognized that only a *tightly* packed ball of neutrons spinning at an incredible rate and beaming radiation as it does so could behave like this. These so-called neutron stars, first postulated in the 1930s, are the collapsed cores of exploded stars. Finding one at the center of the Crab established beyond doubt that this nebula was the wreckage from a supernova.

Since then, the Crab Nebula has probably consumed as much telescope time as any object in space. As one of the sky's brightest supernova remnants across a broad range of wavelengths, from radio waves to gamma rays, the Crab affords scientists the chance to study a star as it shudders through its last and violent death throes.

Catch the Ghostly Crab



Astronomy: Elisabeth Rowan

The object that prompted Charles Messier to compile a list of objects that look similar to comets is the brightest supernova remnant in the sky. And the fact that Messier could see the object well in the primitive telescopes of the mid-18th century tells you that it is quite easy to pick out in a backyard telescope. A 3-inch scope reveals the Crab as a ghostly glow while an 8-inch on a good night will show mottled structure.

Late autumn and winter are the best times of year to spot the Crab. You can find it just 1° northwest of 3rd-magnitude Zeta (ζ) Tauri, the star marking the southern horn of Taurus the Bull. (This part of Taurus lies just north of the bright winter constellation Orion, making it easy to find.) Taurus rises in the early evening in November and is highest in the south shortly after midnight. By the time the cold winds of January blow, it lies due south at midevening. Although you won't see great detail in the eyepiece, remember as you gaze on the Crab that it didn't even exist a scant — in astronomical terms — thousand years ago. — *Richard Talcott*

A Bowl of Spaghetti

At the center of the nebula is the tiny pulsar, a neutron star whose 30-times-per-second rotation is tilted about 30 degrees from our line of sight. As the pulsar rotates, its magnetic poles sweep past us like lighthouse beacons, causing the famous pulses.

For almost thirty years now, scientists have been studying this pulse pattern. They have found that the Crab beats with the double beat of a typical human heart, a main pulse followed immediately by a weaker pulse, with a higher "bridge" of energy in between. Every ten minutes or so comes a "mega" pulse, with a strength about a thousand times that of normal, and every three to five years a "glitch" appears in the pulse rate, when the pulsar's spin suddenly increases and then slowly returns to its old rate after several weeks.

Though astronomers know that the mega pulses are triggered by powerful electrical fields within the pulsar's 1,000-mile-high magnetosphere, they do not yet comprehend their cause. "This is an enormously complex process, and we really don't understand the specifics," says James Cordes of Cornell University.

Some astronomers think that the glitches take place when the pulsar's magnetic axis shifts relative to its rotational axis. Others believe they result from starquakes that take place in the neutron star's crust. This crust, only a few thousand feet thick, floats on an ocean of superdense neutrons. The spin rate of the pulsar causes the ocean layer to form tiny atom-sized whirlpools, not dissimilar to the much larger hurricanes on Earth and Jupiter's Great Red Spot.

As the spin rate slows, the star wants to reduce the number of vortices, moving them outward into the crust. But they can't move because they are pinned to the crust's dense crystalline lattice. When the pressure has built sufficiently, however, there is a sudden release, some vortices escape, the star's crust shifts a couple of inches, and a starquake results. This transfer of angular momentum causes the glitch, thereby increasing the spin rate of the entire star for several weeks.

Meanwhile the pulsar's whirl acts as a powerful dynamo, producing a magnetic field that spans a dozen light-years. This field is incredibly strong, generating an electrical field of about 243 trillion volts per foot on the surface of the pulsar while also emitting 1,800 thousand trillion amperes of energy per second. Like a cyclotron used to accelerate particles, positrons and electrons fly outward at almost the speed of light, following the magnetic field's lines of force. As these charged particles are accelerated by the magnetic field, they produce what is called synchrotron radiation, which can be seen as the hazy white inner cloud of the Crab.

The Crab's energy output is mind-boggling by human standards. Were this tiny pulsar to replace our sun, the visible light hitting Earth would increase by a modest six times, but the x-ray energy would be 250 times more intense and the solar wind would blow 130,000 times more powerfully. "You'd be cooked almost instantly," says Hester.

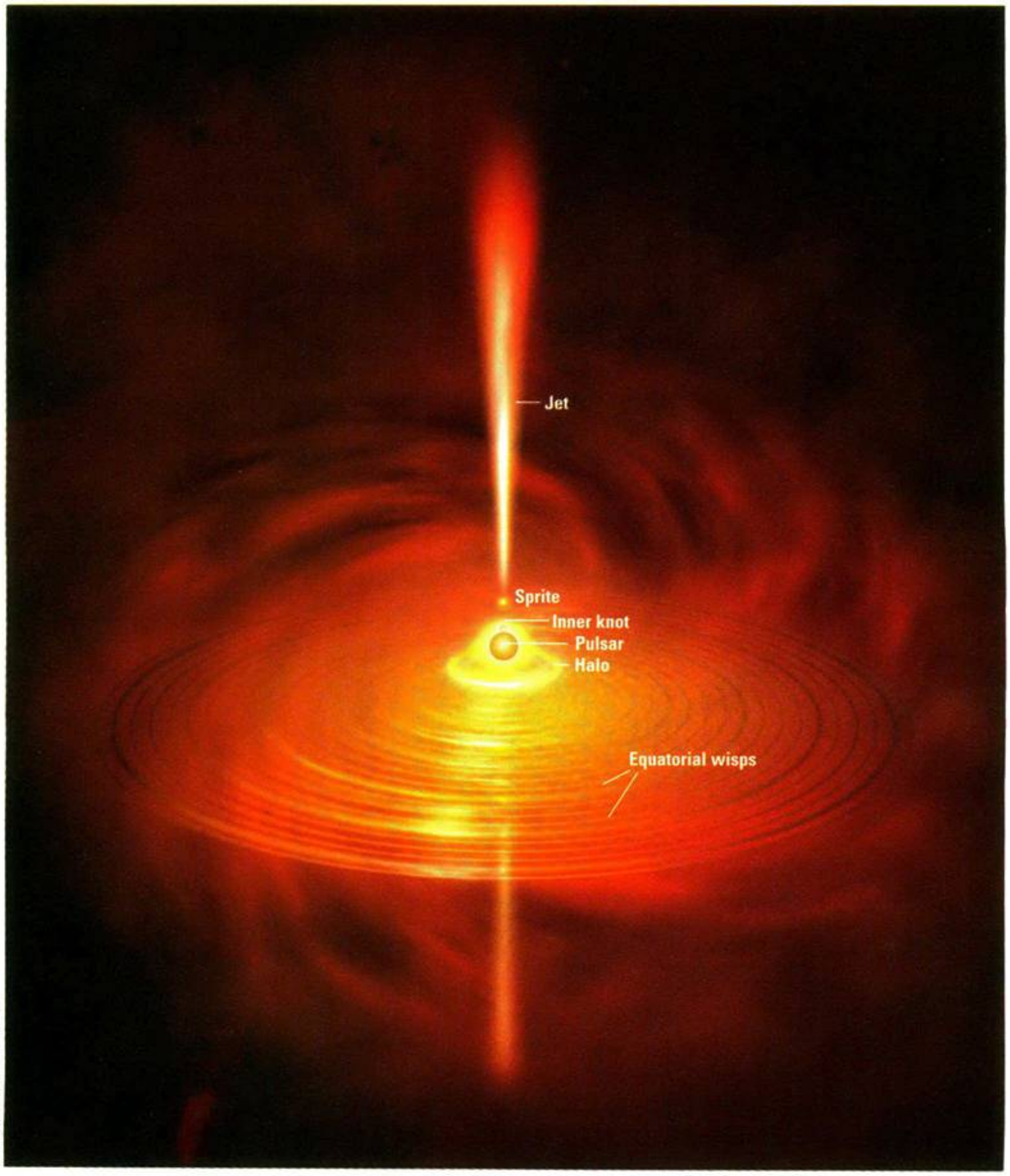
Much like the sun's solar wind, the Crab's synchrotron wind does not fly away equally in all directions. At the equator roll waves of expanding concentric ripples, sweeping up supernova debris before them. When a team of astronomers used the Hubble Space Telescope to take eight pictures of this region over five months in 1995 and 1996, they could actually see these waves surge outward from the pulsar at apparent speeds ranging from 40 to 70 percent of the speed of light. As the waves hit the thicker nebulous clouds, they would pile up and slow down, producing arclike wisps. The wind would then race outward, dragging the magnetic field lines with it as it spiraled away from the star through a complex weave of flux tubes akin to a bowl of spaghetti floating in space.

From the pulsar's poles shoot two high-powered jets. Along the southeast jet's axis, which points toward Earth, were discovered two inexplicable knots of matter. The larger knot, approximately 140 billion miles from the pulsar and about 10 billion miles across, was the brightest feature in the entire synchrotron cloud in 1994. The astronomers found that over a six-month period it actually appeared to move closer to the neutron star, and that the knot's light was highly polarized.

Farther out along the axis, almost a trillion miles from the pulsar, is what the scientists have named the "sprite," because it seems to dance about from Hubble picture to Hubble picture. The sprite sits within a previously known thick cloud called the Anvil, and is now thought to be a shock in the relativistic jet as it plows out through the synchrotron nebula.

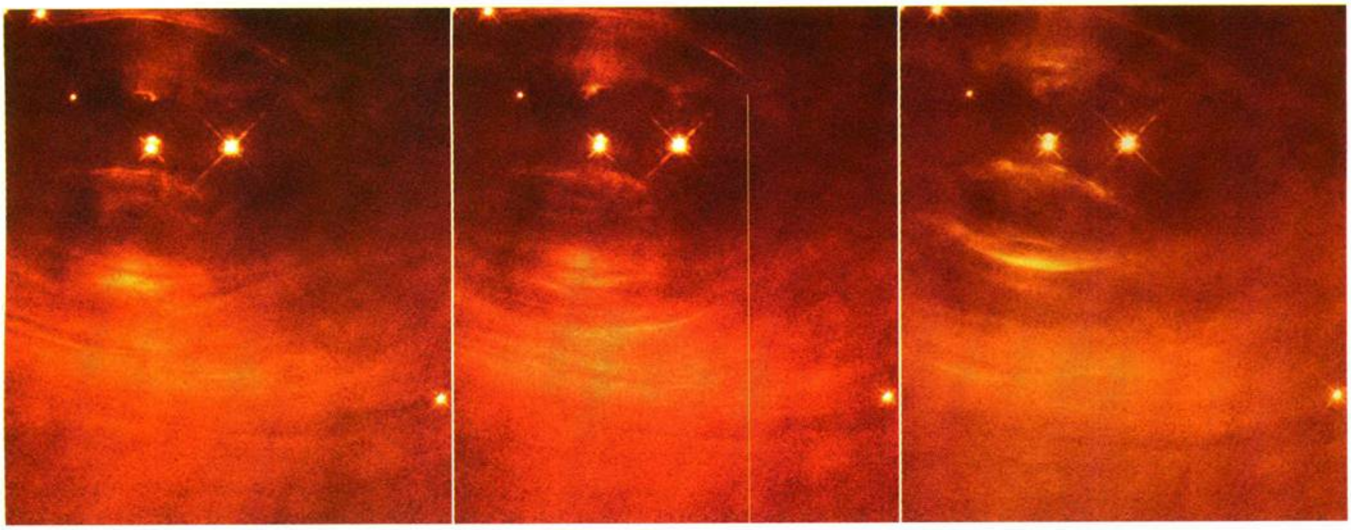
No one really understands entirely what these two knots are. "When I show these pictures to theorists they get real uncomfortable," notes Paul Scowen of Arizona State University. "None of their theories had predicted such objects."

As the charged particles fly outward through the magnetic spaghetti, they push against the outer shell of dust and helium gas ejected when the star exploded and which now lies about six light-years from the pulsar. This wind pressure creates a type of cloudy "skin," the delicate weave of red and violet filaments and knots that seem to surround the central synchrotron cloud. As the wind presses against these outer cloud banks, the denser knots, some as large as 150 billion miles across, more successfully resist being blown away. Instead, as the wind blows past each knot, long



At the heart of the Crab lies a pulsar — the crushed remnant of an exploded star. The pulsar powers the twin jets of high speed particles and the outward moving equatorial wisps. As one of the jets slams into the surrounding nebula, it generates a small "sprite" that brightens, fades, and moves around.

Astronomy: Elisabeth Rowan



Jeff Hester and Paul Scowen (Arizona State University) and NASA

In less than four months in early 1996, the Crab's inner region saw drastic change. That's not surprising since the equatorial wisps, for example, stream away from the pulsar (the left of the two stars at upper center) at half the speed of light. Compare these images to the diagram opposite.

filaments trail out behind, pointing away from the pulsar and appearing reminiscent of gargantuan cometary tails.

This interaction between the inner synchrotron field and the outer skin locks the Crab Nebula into a gigantic electronic cage. While the electromagnetic energy of the inner synchrotron cloud is very good at ionizing matter, it can't cross the conducting field of such particles. When it hits the outer cloud banks, it immediately ionizes them, thereby creating the very trap that holds it.

Not Enough Energy

Despite the vast size and scale of this energetic object, it is still too small to fit the facts. As Dale Frail of the National Radio Astronomy Observatory notes, "The amount of energy and matter that we see in the Crab is on the order of one percent of what a type II supernova should produce." A type II supernova — one caused by the collapse of a star having at least 8 to 10 solar masses — should fling its explosive debris at speeds ranging from 3,000 to 6,000 miles per second. The Crab contains less than half this mass and the fastest moving sections of its outer nebula move at less than a third this speed. After 1,000 years of expansion, the nebula is still much too small.

In 1977, Roger Chevalier proposed that the missing material was hidden in a much larger invisible shell surrounding the visible nebula. Such a shell would not only account for the missing mass, it would be expanding at the velocity expected for a type II supernova while also being the right size.

Unfortunately, most astronomers have been unable to find this outer shell. Recent radio observations by Frail have indicated that it simply does not exist. "We've looked deeper than anyone has ever, and we should have seen something. There was nothing there."

Still, some believe that the shell exists. Because the Crab is located more than 600 light-years above the plane of the Milky Way Galaxy in a particularly empty part of space, they think the supernova blast wave dissipated so quickly that it is now undetectable. Hester and Ravi Sankrit, a graduate student at Arizona State, propose that the outer "skin" seen in the Hubble photos represents the collision between the synchrotron radiation and the inner regions of this invisible shell.

Other astronomers discount the possibility of an invisible shell, and are looking more closely at the visible knots and filaments. More recent Hubble photos taken by a team led by William Blair at John Hopkins University indicate that at least some knots appear at least ten times denser than originally thought, and might possibly contain some of the missing mass.

Yet, more problems remain. The elements in these filaments do not fit what scientists expect from a type II supernova, which should leave lots of nitrogen in the nebular cloud. Not only does there seem to be a lack of nitrogen, but it is distributed unevenly throughout the cloud. While the northern filaments are rich in nitrogen, in the south sulfur dominates, and some knots seem to contain a surprising quantity of argon.

In the next few years astronomers will take more photos of the Crab and hope to answer some of these questions. For example, Hester's team plans to use Hubble to take one picture every ten days for a nine-month period that was scheduled to begin in August 1998. "We can't wait to take these pictures," says Hester. "We've seen enough to know that there are fascinating things going on, but we haven't seen enough to really know what they are."

While the astronomers might be impatient, time is not really a problem. Though the Crab Nebula represents a star in its final agony, the death watch is expected to last for at least another million years.

Robert Zimmerman is a frequent contributor to Astronomy. *His book,* Genesis, the Story of Apollo 8, *about the first human journey beyond Earth orbit, has just been published by Four Walls Eight Windows.*

Exploding Stars Tell All

Distant supernovae hint that the universe will expand forever — and at an ever increasing rate.

by Robert Irion

For sheer explosive spectacle, few events rival supernovae. These titanic bursts of light pierce the cosmos, blazing so brightly that telescopes halfway across the universe can detect them. Now, two teams of astronomers are using these beacons in a most surprising fashion: as probes of how the expansion of the universe has changed.

Their preliminary answers, reported early this year, should delight the existentialists among us. It appears there's not enough mass in the universe to prevent it from expanding forever into a cold, bleak future — indeed, not even close. Further, evidence is mounting that a "cosmological constant" is at work, accelerating the growth of the universe via a repulsion of space so bizarre that Albert Einstein derided its appearance in his equations as his greatest blunder. This effect may inflate the very fabric of space at an ever increasing rate.

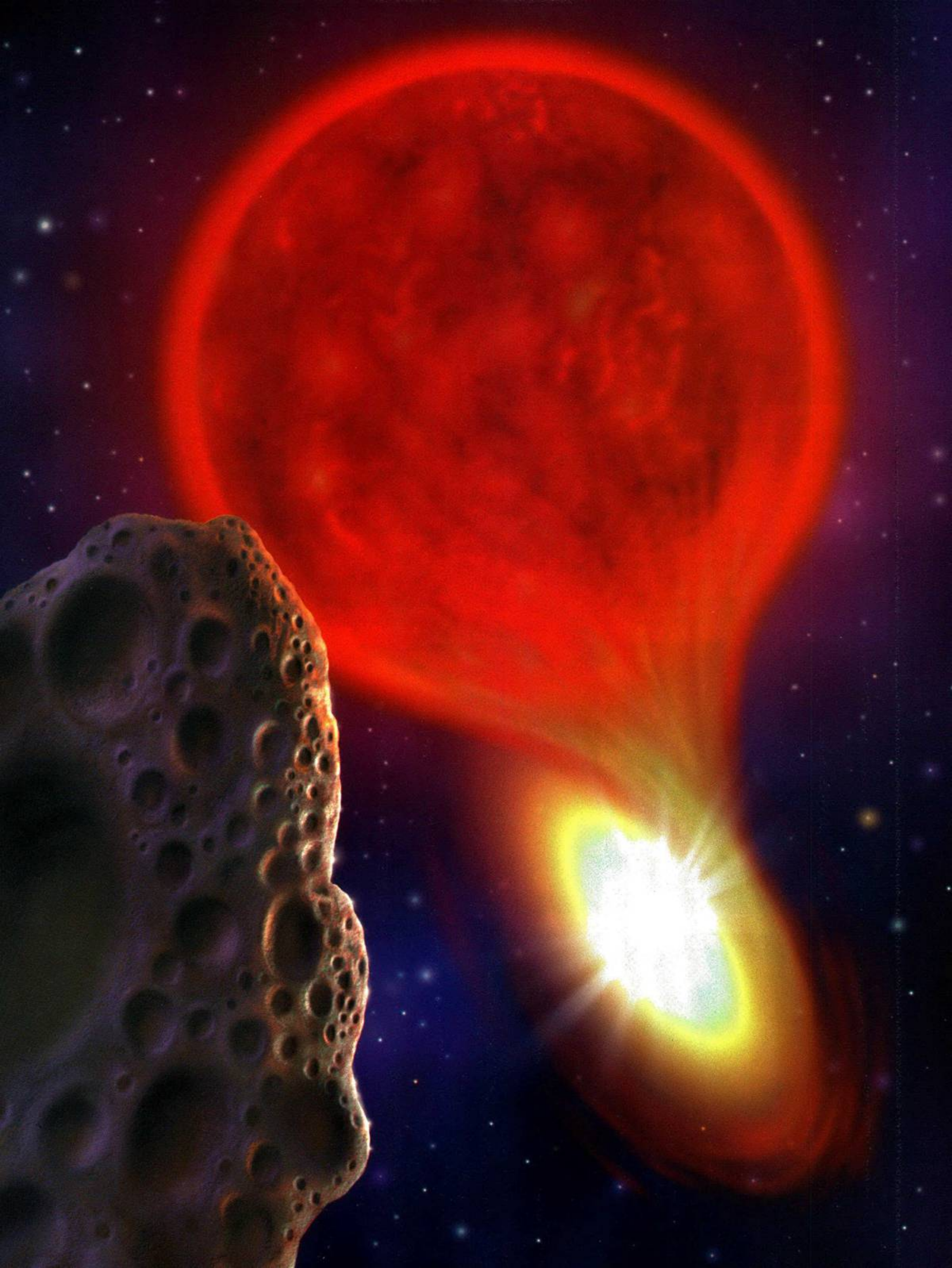
Building a case for these claims has led to spirited competition between the teams, featuring rapid-fire observations with the Hubble Space Telescope and powerful telescopes on the ground. The researchers have devised a way to spot a whole passel of supernovae among images of thousands of faint galaxies, an ingenious method that seemed impractical a few years ago. They also have learned how to use supernovae as "standard candles" — brilliant flares that burn and fade with predictable intensities, thus revealing their distances from us in the dark recesses of space.

Many questions remain, but astronomers agree that supernovae have become a promising means to gauge our ultimate fate. "Measuring these cosmological parameters ties us to questions that go back thousands of years," says astrophysicist Saul Perlmutter of the Lawrence Berkeley Laboratory (LBL), leader of the group that pioneered this method. "It's so rare to get at these numbers with such a straightforward, elegant technique. This is an incredibly exciting project."

Perlmutter talks about his endeavor with supernova-caliber energy, darting across an office that overlooks the Golden Gate Bridge miles to the west. The project, he says, is a curious hybrid of classical astronomy and modern physics. Its goal — to ascertain the curvature of space — recalls Edwin Hubble's pioneering work in the 1930s. However, the research smacks of particle physics: large collaborations (more than 20 scientists on each team), a reliance on automated analysis, and an approach that discards almost all the collected data to expose hidden events. It's no accident that many in Perlmutter's group were trained as physicists — and it helps explain why it took the better part of a decade to prove the concept.

But by now, Perlmutter and his competitors — a consortium headed by astronomer Brian Schmidt of the Mt. Stromlo and Siding

George Krauter



Cerro-Tololo Inter-American Observatory

The death of a massive star created Supernova 1987A (seen at right), a type II supernova that was the brightest in nearly 400 years.

Spring Observatory in Australia — have done just that. "I'm deeply impressed," says cosmologist P. J. E. Peebles of Princeton University. "It's a great triumph, and Saul deserves a lot of credit for pushing it forward." Nonetheless, Peebles thinks the rivalry has led to hasty public notices. "I depreciate this announcement that we've discovered how the world will end," he says. "I don't think we know. And it's a little embarrassing at this stage to say that we do."

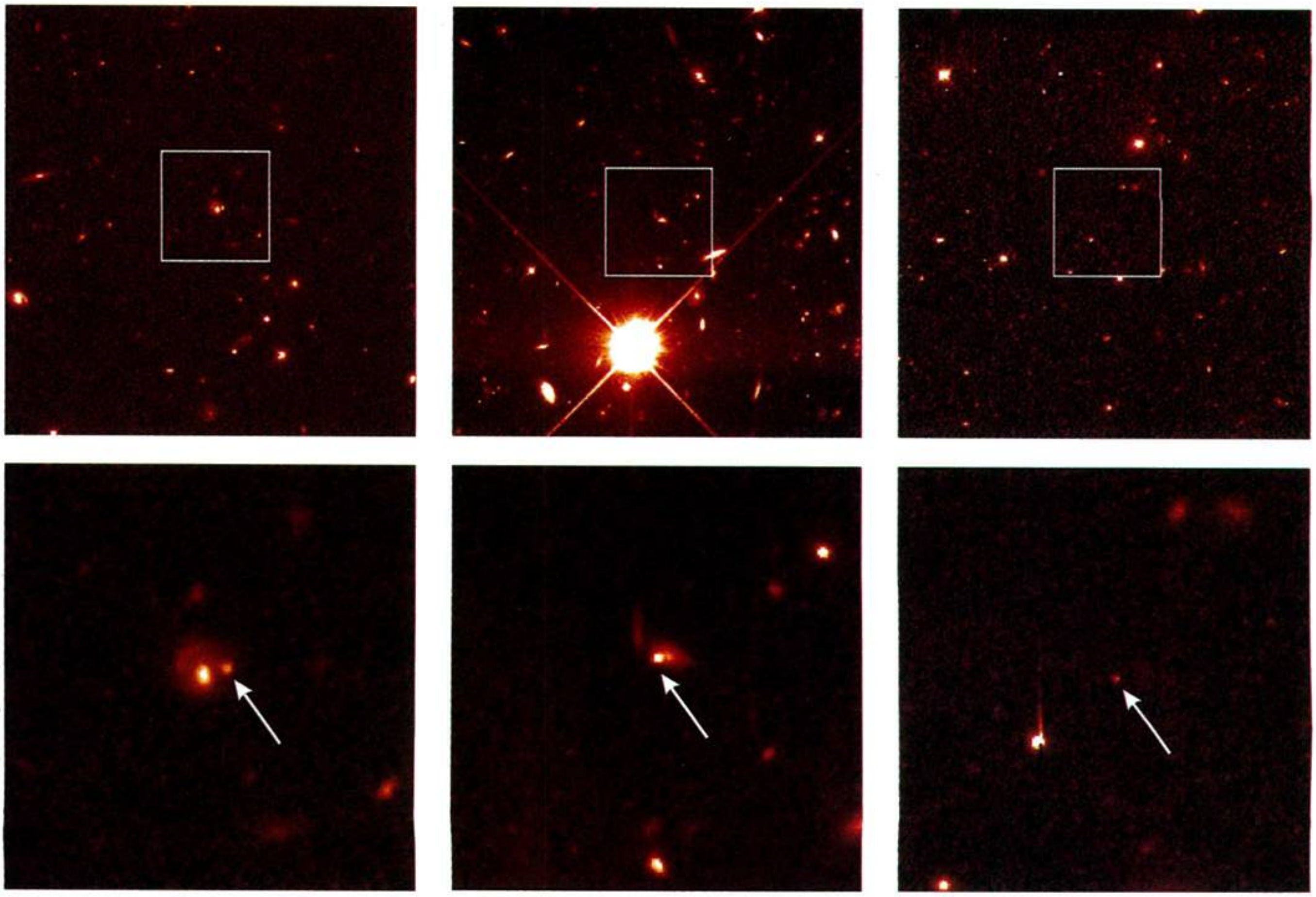
Perlmutter and Schmidt agree their groups must check many potential errors over the next year or two. "As physicists we know what it means to announce a new particle and then be proven wrong," Perlmutter says. Adds Robert Kirshner of the Harvard-Smithsonian Center for Astrophysics (CfA), a senior member of Schmidt's team: "These are surprising results. People ought to be skeptical until we're sure that we've done everything right."

Thermonuclear Booms

The teams both chase a kind of supernova called a type Ia. Famed Supernova 1987A was a type II — a supergiant star that uses up its nuclear fuel and blows itself to bits. A type Ia, on the other hand, is the cataclysmic death of a white dwarf orbiting a bloated companion star. The dwarf, about the diameter of Earth, pulls gas from its companion and builds mass until it reaches 1.4 times the mass of our sun. At precisely that limit, the pressure becomes so intense that the dwarf fuses carbon at its core. That ignition happens ferociously. Within seconds, the star detonates like a planet-sized thermonuclear bomb. Such explosions, the brightest in the cosmos, often outshine entire galaxies for a few weeks and occur about twice a millennium in a typical large galaxy.

The trick is to spot lots of type Ia supernovae on demand. The clever scheme, honed by Perlmutter's group and since adopted by both teams, works like this: In the dark skies at the time of the new moon, the astronomers take about 50 deep exposures with the 4-meter telescope at the Cerro-

Hubble observations of distant supernovae (images in the bottom row are close-ups of those above) reveal a universe that will expand forever.



Peter Garnavich (CfA), the High-z Supernova Search Team, and NASA

UNIVERSE WITHOUT END?

Measuring the light from distant supernovae is one of the most direct ways to probe the expansion of the cosmos. However, several other ongoing studies are yielding the same early finding: The universe contains just 20 to 30 percent of the mass needed for gravity to reverse the expansion and eventually bring about a "Big Crunch."

For instance, Marc Davis of the University of California, Berkeley, measures the motions of numerous galaxies out to distances of more than 100 million light-years. When he subtracts the part of the motion created by the universe's expansion, Davis finds the galaxies actually move quite slowly. If there were more matter in the universe, the resulting gravity would increase the velocity of these so-called "bulk flows."

Groups of extremely remote galaxies lead to similar insights for Neta Bahcall of the Institute for Advanced Study in Princeton, New Jersey. Massive clusters arose when the universe was fairly young, says Bahcall, so the total gravitational pull from all matter must be relatively weak. Otherwise, those clusters would have grown into titanic assemblies of galaxies by now — and astronomers see no evidence of that.

Ruth Daly of Princeton University uses yet another technique: radio galaxies that emit pairs of "hot spots" at the ends of violent jets of matter. The predictable separations between those hot spots allow Daly to determine their distances from Earth. Then, she deduces the overall curvature of the universe in a way similar to the supernova method. To date, the results agree.

The concurrence among these diverse approaches makes astronomers confident that their work will hold up. "It's becoming quite clear," says Daly, "that the universe will expand forever." — *R. I.*

Tololo Inter-American Observatory in Chile. Each field contains thousands of faint galaxies in an area one-third the size of the moon. Three to four weeks later, they collect new images of the same fields. Odds are that among the more than 100,000 galaxies, at least a dozen supernovae popped during that interval. Finding them requires fancy computer programs — and skilled human eyes.

The software sifts through the two sets of images, flagging any blobs of light in the second batch that weren't in the first. Most are blips from cosmic rays or transient objects, such as asteroids. But a precious handful are genuine type Ia supernovae, some so distant that their bursts of light took 5 billion years or more to reach Earth.

Identifying possible supernovae from among the specks is arduous. It's as much art as science, says physicist Gerson Goldhaber, one of Perlmutter's colleagues at LBL. Peering over his shoulder the morning after a flood of data arrives from Chile, one sees why. Scene after scene of "before" and "after" galaxy images flit by; Goldhaber dismisses most of them with curt comments such as "ugly shape," "looks phony," "probably junk." A promising blob bulging from one galaxy meets with approval: "looks like a pretty classic supernova." But to an untrained witness, it's just so many dots on a screen. "I'm obviously using my judgment here," Goldhaber says with a smile.

Eyes go batty after hours of this, but the rewards are worth it. "It's neat to go home and tell my sister that we just found another star that blew up before the Earth formed," says Robert Knop, a postdoctoral researcher at LBL. Indeed, the supernovae rank as the most distant individual stars — albeit exploding ones — ever seen by scientists.

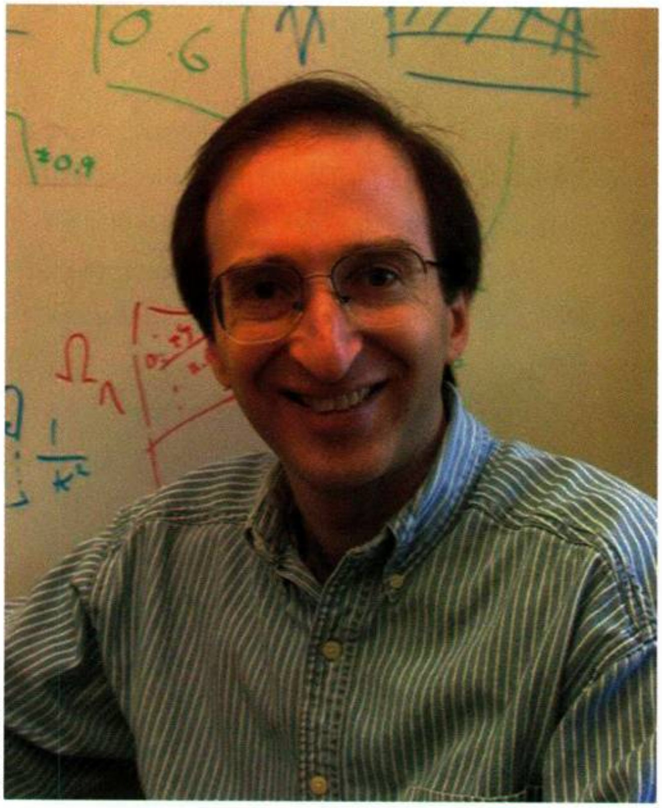
The researchers next must verify each candidate as a type Ia supernova, rather than a flickering quasar or other object. They do this by obtaining its spectrum, usually at the W. M. Keck Observatory in Hawaii. A supernova emits a telltale pattern of light dictated by the silicon, calcium, and other elements it forges. One of the twin 10-meter telescopes at Keck can reveal that elusive pattern within an hour and differentiate a type Ia, which contains no hydrogen, from the hydrogen-rich type IIs. The spectrum also reveals each supernova's redshift — the degree to which the expansion of the universe has stretched the supernova's light. The farthest one yet observed, by Schmidt's team, had a redshift of 0.97. That means the universe is roughly 1.97 times bigger now than it was when the star died; in other words, the universe was half its current age of 12 to 15 billion years.

Finally, the teams measure the light output from each supernova at large telescopes scattered on four continents. The most distant events are targeted by the Hubble Space Telescope, which can follow the gradual dimming of a supernova with exquisite precision.

Standard Candles

The resulting "light curves" are crucial. One might think all type Ia supernovae act the same because they erupt from the maws of identically sized white dwarfs. However, each one varies somewhat in its brightness and in how quickly it wanes to obscurity. Features in the light curve allow the researchers to fit each explosion to a common template. "When we apply our correction factors, the supernovae become virtually indistinguishable," says Alex Filippenko, an astronomer at the University of California, Berkeley, and a member of Schmidt's team who has contributed to both groups. The teams thus transform events of unimaginable violence into the long-sought standard candles of cosmology — objects of known luminosity that shine across great reaches of space.

Peter Garnavich, a postdoctoral researcher at CfA, compares this process to "reading the labels on light bulbs" dangling throughout the universe. For example, imagine a



Saul Perlmutter

Saul Perlmutter of the Lawrence Berkeley Laboratory in California heads the Supernova Cosmology Project, which so far has discovered and examined more than 40 distant type Ia supernovae.

row of 100-watt bulbs hanging within a special room with a dark rubber ceiling and walls. A bulb 10 feet away from you will look 4 times brighter than a similar bulb 20 feet away, 9 times brighter than one 30 feet away, and so on. If the entire room starts stretching (just as space itself grows), the bulbs will recede and seem to get dimmer at a certain rate. In a similar way, the researchers can compare the redshifts of their supernovae with their actual distances — as measured by their "wattages" — to gauge how the entire universe has expanded over time.

As of April, Perlmutter's team had done this for more than 40 supernovae, while Schmidt's group had 16. Both teams had at least two dozen more under analysis. But even the conclusions from those few stars raised eyebrows — and landed one member of Schmidt's team, postdoctoral researcher Adam Riess of UC Berkeley, on national television to explain why we may face a frigid future.

The first result concurs with several other studies: the universe is expanding too quickly for gravity to stop it. Indeed, the rate at which type Ia supernovae are flying apart implies that the universe contains only about 30 percent of the critical mass needed to halt its growth. "A universe bound by matter simply does not agree with these data," Kirshner says.

More provocatively, both groups say their most distant supernovae are 10 to 15 percent fainter than expected, given their redshifts. That is, it appears the expansion of space has recently *sped up* after stretching more slowly since the stars exploded billions of years ago, thus pushing them farther away from us than one would predict if gravity alone ordained the expansion rate. It's a weird idea that unsettles just about everyone, for it may mean that some mysterious pressure pervades all of space — repelling space from itself with increasing magnitude as the volume of the universe grows. Astrophysicists can't explain this phenomenon, but they have a name for it: the cosmological constant, symbolized by the Greek letter lambda.

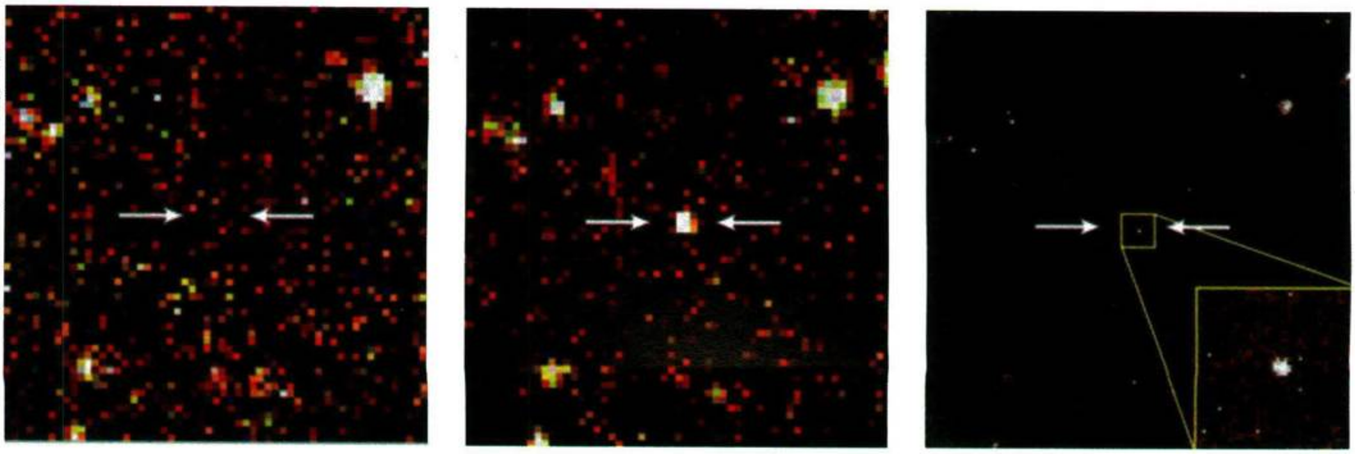
Cosmological Conundrum

"I find lambda painful and distasteful," says cosmologist Rocky Kolb of the Fermi National Accelerator Laboratory. Kolb is not alone. Twice this century scientists have invoked the cosmological constant to account for features of the universe that did not exist: Einstein, to explain what he thought was a static universe, and Fred Hoyle in the 1950s for his steady-state theory of continual creation of matter. "It's like a siren of cosmology," Kolb says. "Whenever we're in trouble, we hear it sing. Perhaps our ship is going on the rocks again."

Even so, many theorists are entertaining thoughts of lambda more seriously than ever, not least because of the supernova results. Fermilab cosmologist Michael Turner has advocated lambda for years as a key part of theories that yield a "best fit" to observations of galaxies in the distant universe. New satellite probes of the faint microwave glow that suffuses the cosmos, together with other measures of the universe's mass content, should make or break the case for lambda next decade, Turner believes.

But if it's real, what is the cosmological constant? Where does it come from? The facile answer happens to be true: No

This distant supernova was discovered at Cerro-Tololo (left two images, before and after the explosion) and then scrutinized by Hubble (right).



Saul Perlmutter (LBL), et al. and the Supernova Cosmology Project

© Anglo-Australian Observatory; photo by David Malin

The brightest type Ia supernova in four centuries exploded in 1986 in the nearby galaxy Centaurus A. The supernova appears as a greenish dot (in the dust lane) because the red-light image was taken a year later.

one knows. It is not, as many reports have stated, an "antigravity" force, for it has nothing whatsoever to do with matter. Rather, it derives from a suspected physical property of space called the "vacuum energy." It is as if space itself has some infinitesimally small "weight," in Kolb's words, that impels it to expand. The more space, the greater the expansion. With time, that effect can overcome the attractive force between matter that tends to slow down the universe. If lambda exists and truly is constant (which not all cosmologists accept), that expansion may accelerate *ad infinitum*. In the simplest terms, space itself would explode.

Or so the hand-waving goes. "In our present state of ignorance, we have no understanding about why lambda should have any value at all," says cosmologist Joel Primack of the University of California, Santa Cruz. When physicists calculate lambda based on current theories, he observes, they get a number more than 100 orders of magnitude *bigger* than claimed by the supernova teams. Even for astronomers, that's a whopping gap.

Naturally, the supernova projects face tight scrutiny. "It's unlikely both teams have made the same giant blunder," says Filippenko. "Our statistics are very good, but some sneaky effect could mess things up."

For instance, supernovae might explode less vigorously in the early universe, because the ratios of various elements have evolved over time. If ancient supernovae were dimmer on average, their distances would once again make sense; no lambda would be needed. However, Schmidt's team has explored nearby supernovae in diverse settings — old stars and young, gaseous regions and gas-free. "Everything we've checked out so far says that supernovae billions of years ago look very similar to the ones of today," says Garnavich. The peaks and valleys of the spectra of distant and nearby supernovae match beautifully, Perlmutter adds — another indication that they haven't changed much as the universe has aged.

Kirshner describes another worry: "What is the thing that ruins most astronomical inferences?" he asks. "I think it's dust." If blankets of dust swaddle distant galaxies, Kirshner says, that would make these supernovae appear both dimmer and redder than they really are, like smog dulling the setting sun. But the scientists think any such dusty patches would lead to data possessing far more fluctuations than they see.

A more insidious factor is observational bias. Oddly enough, it's more challenging for the researchers to find lots of nearby supernovae, because fewer close galaxies inhabit any chunk of the sky. Yet such events are vital, for they help calibrate the light curves of the distant ones. Although Schmidt's group has data for about 50 nearby supernovae, both teams are addressing concerns that those objects might be brighter or somehow different than the rest.

"These cross-checks should be done within the millennium," says Perlmutter. "By then we should know whether we live in a universe that will ever come to an end." And, he might add, we also may learn whether space itself is doomed to inflate as wildly as the most spectacular supernova. ■

Robert Irion toyed with the idea of an astronomy degree before turning to full-time science writing in Santa Cruz, California. This is his first article for Astronomy.

Astronomy's

Roger Angel is more than a virtuoso mirror maker; he is
a maestro of innovation shaping the premier telescopes of the next century.

by Rex Graham

Telescope innovator Roger Angel spins out new ideas the way the Arizona desert produces dust devils on a hot afternoon. He once dreamt up an ingenious x-ray telescope based on the matrix of square, light-gathering cells of the lobster eye. He obtained glass pans (a new, flame-resistant style of Corning called Vision) from a Tucson bank in exchange for opening an account. He melted the Pyrex dishes in a small potter's kiln in an experiment which showed that borosilicate glass can be melted in telescope-mirror molds bigger than backyard swimming pools. (With his cookware discovery, and a vision he shared with Arizona colleague Neville Woolf, he founded the renowned Mirror Laboratory at the University of Arizona.)

Angel also is making a new kind of mirror, called an adaptive-optics mirror, for ground-based telescopes. That technology involves taking light from a telescope's concave primary mirror and bouncing it off a two-millimeter-thick, convex secondary membrane-mirror. An array of tiny loudspeaker coils behind the secondary mirror subtly bends it in a way that counteracts the light-blurring effects of atmospheric turbulence. Objects that may have previously appeared as fuzzy blobs of light resolve with the adaptive-optics technology into groups of individual stars or galaxies. "In the next few years we will see images of very faint objects at Hubble-quality from the ground," says Angel, in reference to the Hubble Space Telescope. "This is done by correcting atmospheric blurring. This is the method of adaptive optics."

Over the past decade, Angel has surpassed his distinction as a virtuoso mirror maker to become a maestro telescope innovator and technologist. He enlivens discussions around the world about how technology can enlarge astronomy's "discovery space" in the next century. He recently won a five-year, no-strings-attached $331,000 "genius" fellowship from the MacArthur Foundation. However, Angel's idea machine already spins at full bore. These days he is thinking about probing deeper in the cosmos with the most powerful telescopes ever imagined.

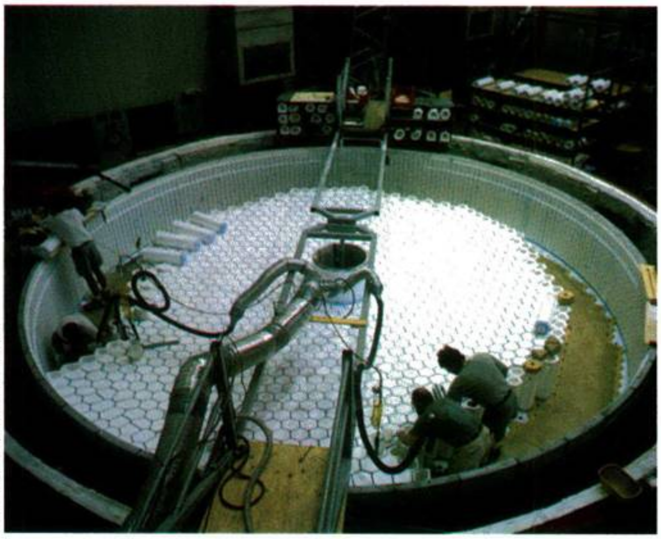
One of the few things that Angel, a Regents professor of astronomy at the University of Arizona, hasn't figured out is a different, new project for the MacArthur money. "I feel guilty about this," he

Doug Hoeschler

Archangel

says, seated one recent day in a chair amid the organized chaos of his treetop-level office on the Arizona campus in Tucson. "I've got a zillion different projects going on and I want to use the fellowship to start something new. The problem is one gets so overextended that starting something different is difficult."

Tall, aslant stacks of papers, a partially unpacked briefcase, and Angel's harried schedule and cheerful, boyish smile give an overall impression of frenzied mirth. A pair of 7x50 binoculars that he bought to see how they could be built for only $20 is buried under an osprey-nest-sized pile of papers on his desk. Phones ring. His administrative associate, Doris Tucker, leans through a doorway and reminds him that a publication deadline is only a few hours away. The text of the paper glows from his desktop computer monitor. About 30 transparencies for a talk he is preparing to give the next day in Los Angeles trail across the floor and extend from Angel's aerie in an L-shaped pattern down a hallway. The line of transparencies passes eight stacks of "working-file" notes, reprints, and reports on what's left of Angel's gray-and-white-flecked vinyl floor. He nods toward the stacks and smiles: "These are hot items."


Following four photos: Lori Stiles

Mirror Lab technicians install hexagonally shaped elements into an 8.4-meter mold for the Large Binocular Telescope.

Ingenious Inventor

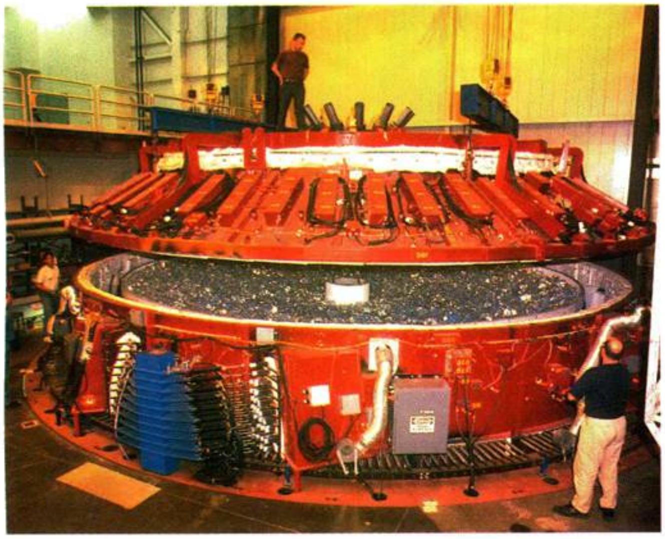
James Roger Prior Angel, 57, behaves as if Yankee ingenuity was invented in Lancashire, England, his birthplace. The son of a career chemist at Pilkington Glass, a Lancashire glass-making company, Angel trained as a physicist at the California Institute of Technology and at Oxford University. Angel's assured, British baritone voice seems too big for his thin, 5-foot 7-inch frame. The oversized lenses of his glasses droop from a face that otherwise seems perpetually alert, sympathetic, and prepared to smile. The slightly gray-haired Angel favors open collared plaid shirts and has that quintessentially rumpled look of a world-class physicist. He also could blend into a crew of automotive mechanics. Indeed, Angel is a rare amalgam of chalk-board theoretician and tool-box craftsman. "He likes his graduate students to have practical experience," says his wife Ellinor, a physician. "He asks them, 'What have you made?'" When Roger starts "flagging" during evening sessions at work and needs a tea break, he telephones his wife at their cactus-landscaped house and says, "Ellinor, put the kettle on." The couple have two children: Jenny, a 24-year-old biology graduate student at Tufts University in Medford, Massachusetts, and James, a 19-year-old freshman at the University of Arizona.

Angel stokes his creative fires by penetrating to the heart of the most difficult technological questions. Homework while preparing to refine telescope technology occasionally includes reading vintage books: He likes to retrace the thought processes and technological tricks used by technologists. "Roger is tremendously inventive," says Robert Novick, a retired Columbia University physicist and x-ray astronomer who supervised Angel in Angel's early years as a research associate at Columbia. "He would look at a piece of apparatus and decide it wasn't right, take it apart, and put it back together so that it performed much better. You would find a little heap of parts left over and you knew Roger had been there."

Next, the technicians place chunks of borosilicate glass, each of which has been carefully selected, into the mold.

Angel's faintly British accent and cultured civility are disarming. But his professional vocabulary belies a driving intellectual entrepreneurialism rooted in 31 years of academic research in the United States. He has walked fearlessly into NASA Administrator Daniel Goldin's office and offered unsolicited advice. Goldin's mantra is faster, better, cheaper; Angel's is bigger, better, farther. Except for the International Space Station, Goldin wants NASA to launch smaller boxes; Angel not only thinks outside the NASA box, he would disassemble it if given the chance. Angel brings to mind the late cartoonist Reuben Goldberg. Angel favors building the most powerful space telescopes with the fewest moving parts. Goldberg satirized unnecessary complexity and drew Rube Goldberg contraptions that accomplish simple tasks, such as opening a door, in 20 or 25 roundabout steps. Angel is scientific matter; Goldberg was comic antimatter.

"Roger's mind goes from A to B through a very different path than that of everybody else," says Martin Weisskopf, a longtime colleague and chief scientist for NASA's Advanced X-Ray Astrophysics Facility mission. "It makes Roger very difficult to work with . . . not because of his personality, he is not a difficult person. But it is often hard to follow his line of reasoning: When we would be discussing something we were working on Roger would say, 'This is going to be the answer.' And I would say, 'Well, I don't see that. Explain to me why.' And he would give me the five steps of his reasoning. I would think about it, realize he was right, and also notice that I wouldn't have thought to go through those five steps, and in that order." Weisskopf has met few scientists brimming with Angel's creativity. "You need only one or two good ideas to make a career, but Roger's rate of production of good ideas is very high."



Once the proper amount of glass is loaded, the furnace dome is lowered into position and heating begins.

Angel started Arizona's Mirror Laboratory, now led by John Hill, Jim Burge, Buddy Martin, and Peter Strittmatter. However, Angel's mirror-making sojourn offers a glimpse of his idiosyncratic approach.

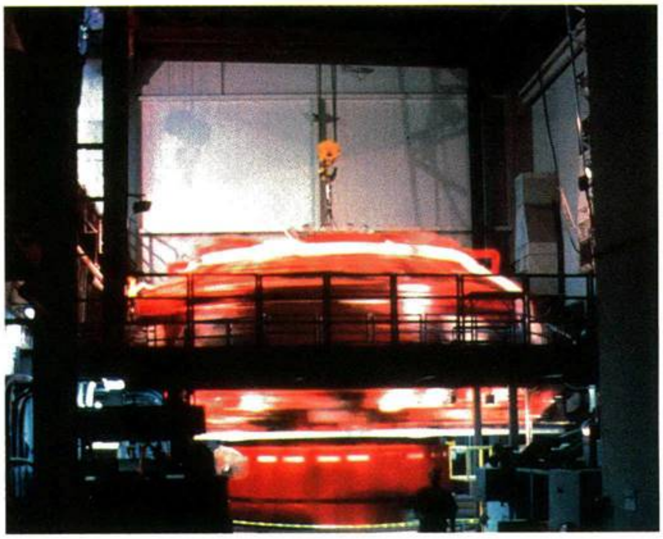
Glass Beeswax

Glass is the best material for telescope mirrors because it is rigid, strong, relatively inexpensive, and can be polished to unparalleled precision. A thin reflective coating of silver or aluminum usually is applied to zero-expansion glass. (If one part of a mirror is cooler than another, a daily occurrence at an observatory, zero-expansion glass maintains its exact shape.) Though zero-expansion glass has become the benchmark material for most modern mirrors, Angel avoids it.

Glass, like cake, comes in almost infinite varieties depending on the kinds of ingredients added to pure silica sand. The color, melting point, temperature-expansion characteristics, and other features can be finely adjusted. The glass preferred by Angel is the beeswax of astronomy — borosilicate glass. Japanese craftsmen make it with a type of pure sandstone and borax, which is obtained from U.S. mines. Unlike zero-expansion glass, which melts at 1800° C, borosilicate glass melts at a relatively cool 1180° C. This feature led George Ellery Hale 50 years ago to use borosilicate to make the 200-inch Hale Telescope at Palomar Mountain, California. Borosilicate-glass mirrors maintain their exact, parabolically polished shape if all regions of the mirror are somehow kept at the same temperature. Such a mirror is said to be in thermal equilibrium.

The Mirror Lab has made 10 borosilicate-glass mirrors in four sizes — 1.8 meters (5.9 feet), 3.5 meters (11.4 feet), 6.5 meters (21.3 feet), and 8.4 meters (27.5 feet). Borosilicate glass, slowly heated to 1180° C, flows like liquefied wax into the Mirror Lab's honeycomb molds. The molds and melting glass are spun in a kiln, and the spinning continues during the cooling, or annealing process, which lasts weeks. The end result is a concave saucer 1.65 inches thick with a honeycombed underside.

"Oven pilots" control every phase of the heating and cooling process in a command center that resembles NASA's mission control. Nothing is left to chance. Auxiliary electrical generators are on standby in case of power outages. The lab, built under the University of Arizona's football stadium, once even hired undergraduates, posted at strategic points, to act as lookouts in case sewage backed up during home games. In another Angel-inspired touch, Mirror Lab scientists have developed a computerized polishing machine that looks like a robotic circular floor sander. It generates the final, exquisitely accurate curvature needed before the glass gets its reflective-metal coating.



The furnace, and the mold within it, spins at seven revolutions per minute during a three-month heating and cooling process.

The advantage of borosilicate over zero-expansion glass is not immediately apparent. It shows up during cold nights at mountaintop observatories. As nighttime temperatures fall, the mirrors remain in thermal equilibrium because Angel's mirrors are "ventilated" with ambient air blown through the hollow honeycombs. On the contrary, thick, zero-expansion-glass mirrors retain heat much longer. As a result, they generate wavy currents of air above the mirror surface. Such convection currents are made the same way as "heat waves" that shimmer from the surface of asphalt roads on sunny days. "People who made thick, zero-expansion mirrors said, 'It doesn't matter if they are not in thermal equilibrium.' But they forgot about convection currents," says Angel. "Their mirrors don't distort incoming light, but the air above their mirrors does."

The Mirror Lab's 3.5-meter (11.4-foot) mirror in the Wisconsin-Indiana-Yale-National Optical Astronomy Observatories (WIYN) telescope demonstrates Angel's point. "The WIYN mirror at Kitt Peak (Arizona) is making much better images than any other telescope on the mountain because it is ventilated," Angel says. "It gets rid of this convection problem."

Angel Eyes Space

The Hubble Space Telescope is one of the few relatively new telescopes Angel has had little to do with. Hubble's technology was developed as part of the United States spy-satellite program. Angel's primary connection to Hubble was his service on a panel of experts that investigated Hubble's flawed 2.4-meter (94.5-inch) primary mirror. Since the shuttle repair mission in 1993, the $2-billion Hubble has demonstrated the many advantages of telescopes that orbit above Earth's interfering atmosphere. Hubble has helped astronomers measure the expansion of the universe, discover black holes, locate very young galaxies, and find what perhaps is the first extrasolar planet to be directly photographed. (Hubble's infrared camera was able to find the suspected planet because it is unusually hot and it seemed to have a prominent trail of hot dust and gas.) Hubble images of planetary nebulae, newborn stars, and other objects have stunned both scientists and the public. Unfortunately, Hubble is expected to wear out by 2005. Its less expensive successor, NASA's $500-million Next Generation Space Telescope (NGST), will allow astronomers to make more fundamental discoveries.

NGST will have better light detectors, a bigger mirror, and a higher, colder orbit to reduce the amount of infrared pollution radiated from the telescope. Currently, the best ground-based telescopes can resolve objects that are, at least, about 0.5 arcsecond apart. (The moon is roughly 1,800 arcseconds wide.) Hubble can resolve objects that are as little as 0.1 arcsecond apart. Ordinary extrasolar planets are thought to lie within an arcsecond of their parent stars, possibly much closer in some cases. They will be difficult for a telescope to distinguish in the visible spectrum amid the billion-times-brighter glare of the parent stars. Seeing a planet orbiting a nearby star would be as difficult as seeing a firefly flash in front of an office building engulfed in flames. (A dozen or so extrasolar planets the size of Jupiter have been detected indirectly from the gravitational "wobble" they impart on their parent stars.)

NASA wants a mirror eight meters (26.2 feet) in diameter for NGST. That space telescope is slated for launch in 2007. The eight-meter NGST mirror is intended to resolve objects that are as close as 0.03 arcsecond apart. The space telescope will use infrared-heat detectors to peer past the warm-mirror glow that usually obscures Hubble's vision. The mission of NGST is to discover how, when, and where the first galaxies formed. However, because of the large size of NGST's mirror, the glare of stars would be diminished. Therefore, in theory, NGST also could locate the reflected visible light from planets orbiting nearby stars such as Altair or Vega — if such planets exist.

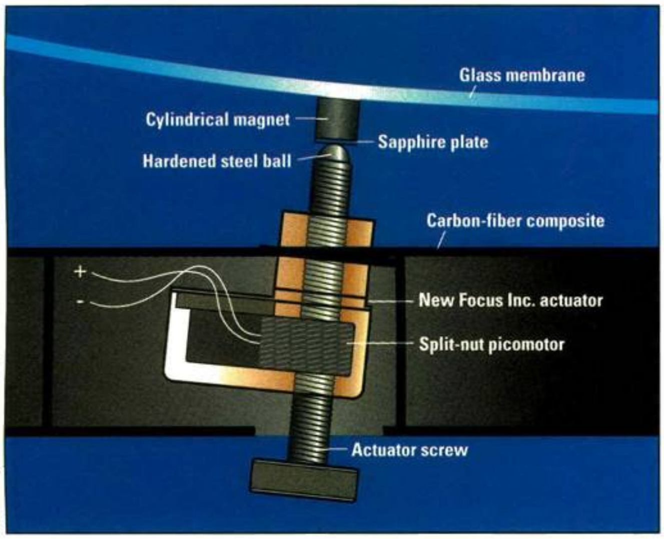
The four teams vying to build NGST are led by Lockheed Martin, Ball Aerospace, NASA's Goddard Space Flight Center, and TRW.

Steward Observatory, University of Arizona

The Giggle Factor

In his typical idiosyncratic fashion, Angel's proposal for the NGST mirror is radical. He thought, why not make NGST's primary mirror a larger version of his two-millimeter-thick adaptive-optics mirror? NASA engineers laughed when they heard about the weird idea. (Angel is notorious among his colleagues for suggesting many odd-sounding ideas during brainstorming sessions, including one for harnessing the power of Arizona's afternoon dust devils. It would be done by first spinning a giant plastic bag of hot air, anchoring the bag in one spot, and releasing the twirling air to initiate a dust devil.)

Aware that he was in danger of being laughed out of the NGST competition, Angel and his Mirror Lab team, led by Steve Miller, actually made a half-meter prototype of their proposal in only three months. Angel unveiled the prototype in 1996 at a NASA meeting in Greenbelt, Maryland. The prototype was incredibly light, tough, and inexpensive. It also showed near-Hubble-image quality in its first laboratory tests. The sight of the unconventional mirror and its test data stunned the audience of scientists and engineers involved with competing teams. The laughter had vanished. Angel had scored another technical coup. Or had he?



Astronomy: Elisabeth Rowan

ABOVE: The Mirror Lab's NGST prototype mirror is attached to a support structure using picomotor actuators that move up and down. LEFT: This half-meter membrane mirror is the Mirror Lab's prototype for NGST.

"Angel's prototype proved that we can do this NGST project, but what surprised me was how quickly he did it," said John Mather, a Goddard astrophysicist and NASA's project scientist for the NGST. "If he hadn't done it I think this giggle factor would have persisted a lot longer."

Jokes about the bloody "cutting edge" of technology don't faze Angel. He is magnetically attracted to risk. Jim Burge, an optical scientist at Arizona and principal investigator of its two-meter (6.5-foot) NGST Mirror System Demonstration project, often is caught between Angel's genius and project deadlines. "Sometimes it is really frustrating when Roger comes up with this brilliant idea half way through the program," says Burge. "And lots of times the direction really should be changed. But sometimes I have to tell him, 'No, we can't make those changes this time.'"

NASA's Mather also understands the plainspoken Angel. "Roger has a very good sense of what is important and what is not. He was the only person out of all the people giving us presentations (at the fall 1996 meeting) about their ideas who actually had formulas in mind and will work out for you why he thinks his is the right choice."

But the mirror that Angel is convinced is the best is not necessarily what Mather and other NASA officials think will be selected for NGST. The primary reason could be that the initial Angel-Lockheed design was the only one that called for a one-piece mirror. The design, while simpler and more elegant, would require a vehicle whose diameter is larger than the mirror's to lift it into orbit. The other three designs call for segmented mirrors that would unfold like origami butterflies once they were in space.

Angel eschews the very notion of a segmented mirror. He stops short of calling them Rube Goldbergs. Says Angel: "I see the advantages of making the darn thing in one piece and testing it in one piece so that what goes into the rocket works. Right?"

It's the Rockets, Stupid

Apparently, not necessarily. NASA has an unavoidable bottleneck that might make a segmented, folding mirror preferable — the aging Atlas rocket. The Atlas, designed to deliver nuclear bombs to enemy targets, also can inexpensively launch telescopes into Earth orbit. The Atlas, like other United States rockets, limits telescope diameters to 3.5 meters (11.5 feet). NASA considers the nation's largest rocket, the Titan, too expensive for the NGST. Even the shuttle, which hoisted Hubble and its 2.4-meter mirror, can't handle a telescope significantly larger than 3.5 meters. "There is no vehicle presently planned that has an inside diameter bigger than about 4.5 meters," said Mather. "Clearly, a mirror that fits inside it must be significantly smaller. Hence, without a folding mirror there is no hope for a telescope a lot bigger than Hubble."

"That is why the United States is such a small player in the commercial satellite-launch business — because we don't have the rockets," says Angel. "Well, my view is, 'It's the rockets, stupid,' right?"

A frustrated Angel has grudgingly altered his NGST-mirror design. It is a segmented version of his original prototype. But he is not happy about it. He argues that Europe's Ariane rockets hold greater promise for ferrying the much larger space telescopes of the future. Ariane rockets were developed by several European countries specifically as satellite-launch vehicles. The European consortium has spent roughly $7.3 billion to develop the Ariane. The largest Arianes are 4.5 to 5 meters in diameter, but Angel argues that bigger ones could be developed that might accommodate a six-meter mirror.

"Nobody has ever launched a rocket that big," Mather says. "So that would also be a development item, which is not something I think is a low-risk item." In other words, Mather doesn't like Angel's idea.

Indeed, a newly developed Ariane 5 exploded in June shortly after launch from French Guiana while carrying scientific satellites. It bruised Arianespace, the European Space Agency's commercial satellite launching arm. At the same time, smaller Ariane rockets had been considered among the most reliable satellite-launch vehicles.

"I would not like to be the guinea pig that was the first to fly on a new rocket," says Mather. "I believe the success rate of new rockets is actually a lot less than the satellites that are carried by them. In the end, Roger's design may not be the right choice. What we choose for NGST may depend on factors other than how good the mirror is."

Rex Graham is senior editor of Astronomy.

Spying on Planetary NURSERIES

To learn how planets form, astronomers are studying disks that surround young stars.

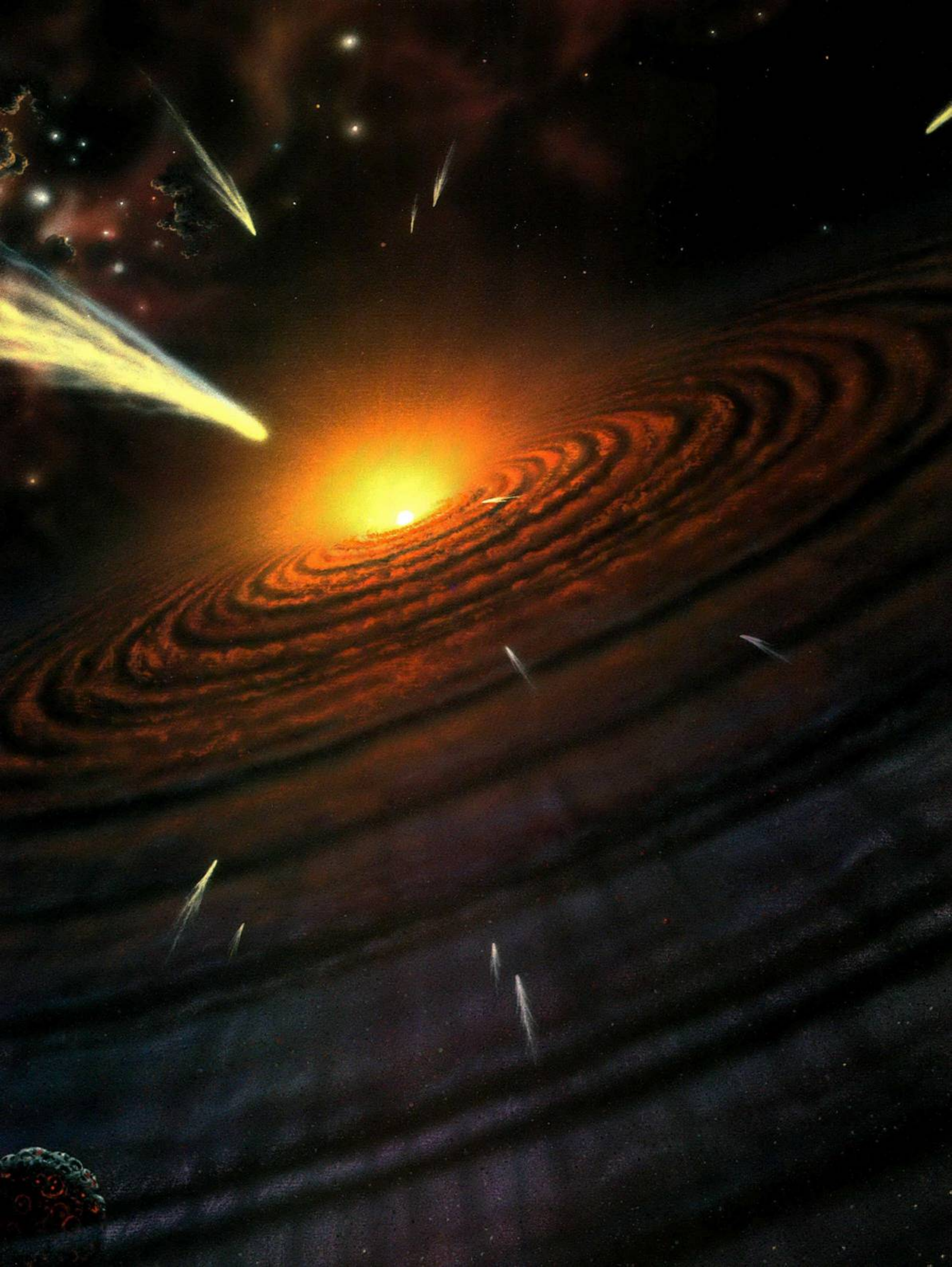
by Ray Jayawardhana

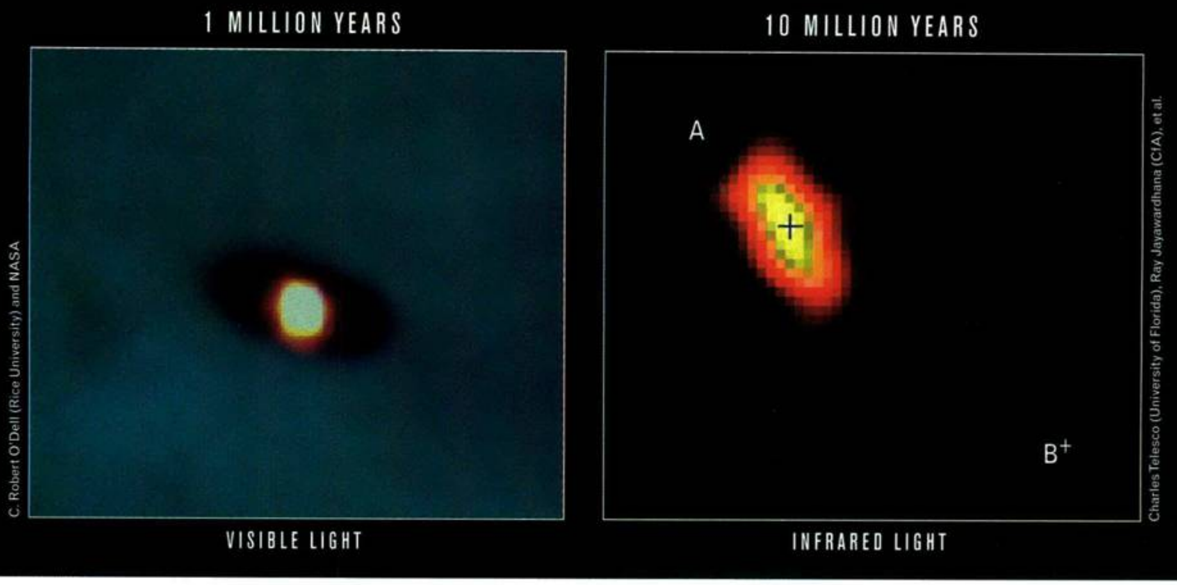
Until recently, we knew of only one solar system — our own. In 1995, astronomers reported the first tentative evidence of planets orbiting another solar-type star. Since then, researchers have detected tiny wobbling motions in about a dozen nearby stars, presumably due to the gravity of planets pulling on them.

The discovery of extrasolar planets begs the question of how planetary systems form. To find answers, astronomers need to look at disks of dust and gas swirling around young stars — planetary nurseries. If you want to know how common planetary systems are, you are better off looking for the nurseries than the toddlers because the surface area of a dust disk is a few trillion times larger than that of a planet.

Within the past year, astronomers have obtained detailed images of dust disks surrounding a host of nearby young adult stars. The images show dust disks at different stages of evolution. Many of the disks appear to have central cavities, perhaps carved out by newborn planets. They represent a missing link between the protoplanetary

Lynette Cook





C. Robert O'Dell (Rice University) and NASA

Charles Telesco (University of Florida), Ray Jayawardhana (CfA), et al.

One-million-year-old disks, such as this one in the Orion Nebula (left), contain mostly gas and show no evidence for planet formation. The disk surrounding the 10-million-year-old star HR 4796A (right) has a central cavity, suggesting planets may have started forming. Most of the original gas has either accumulated into planets or been swept away by the star's wind.

disks observed around even younger stars and the fully grown planetary systems orbiting more mature stars. What's more, these breathtaking pictures offer rare glimpses into the adolescent days of our own solar system, providing insight into how the sun's retinue of planets came into being.

BABY DISKS

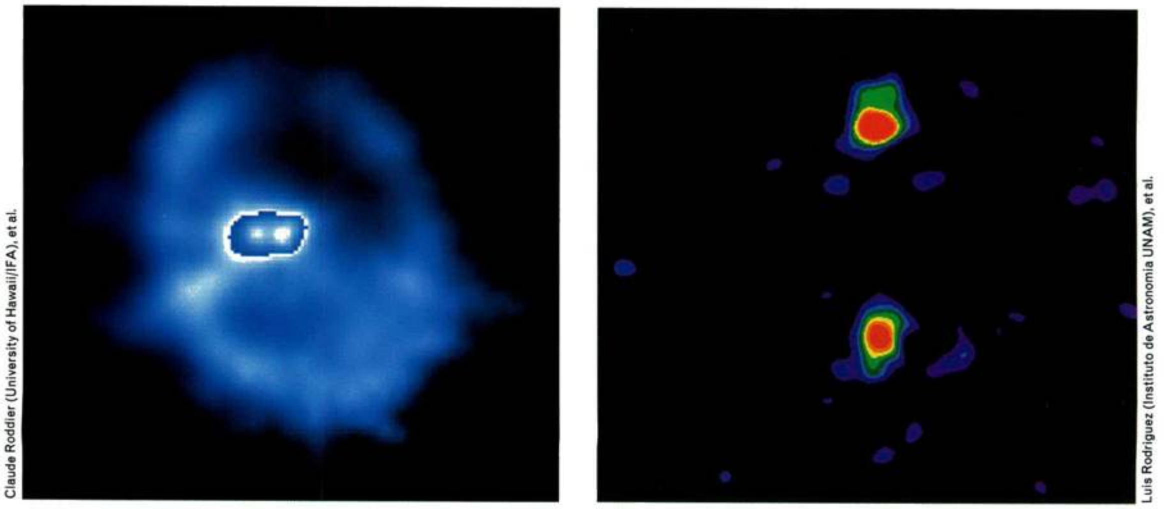
The existence of circumstellar disks comes as no surprise to astronomers — theorists had predicted them decades ago. According to models of star formation, after a star is born from a collapsing cloud of gas and dust, material tries to fall toward the star. Because the cloud from which the star was born is spinning, centrifugal forces prevent most of the gas and dust from falling into the star directly. Instead, it forms a rotating disk around the star. Material in the disk slowly spirals into the star, but some stuff is left behind.

When Rice University astronomer C. Robert O'Dell and his colleagues aimed the Hubble Space Telescope at the Orion Nebula in 1994, they found dramatic confirmation of this long-standing theory. About half of the newborn Orion stars, barely a million years old, are surrounded by disks of gas and dust seen in silhouette against the nebula's bright background. Many of these disks are larger than our solar system.

Even before the Hubble discoveries in Orion, astronomers had indirect evidence of young circumstellar disks. Dust particles in a disk will absorb star light and reradiate the energy at infrared wavelengths. So if a young star has a disk, it will be much brighter in the infrared than one would expect if the star was the only thing emitting infrared light. Even if astronomers could not directly image a disk, they could look for this infrared excess to infer its presence.

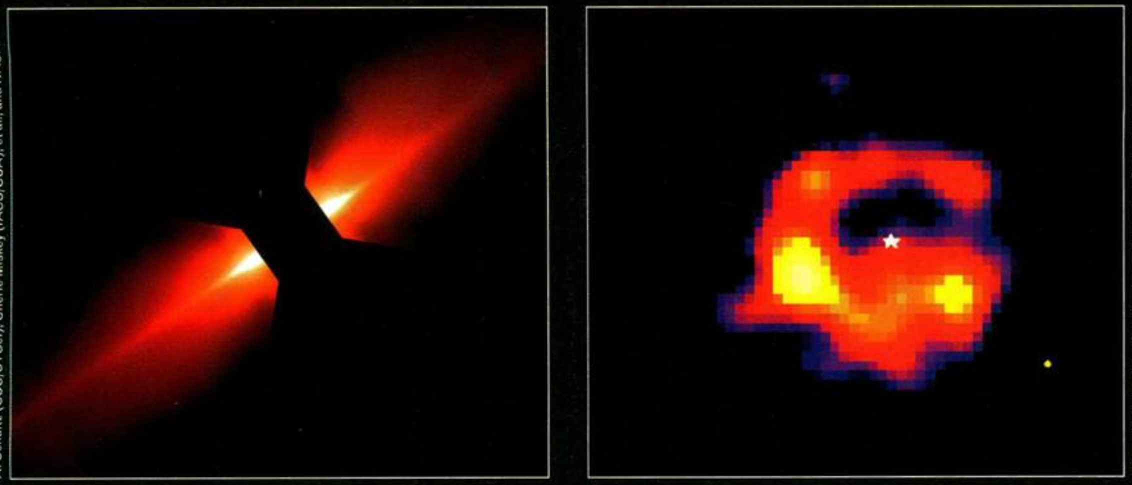
In surveys of nearby star-forming regions conducted over the past decade by Stephen and Karen Strom's group at the University of Massachusetts at Amherst, at least half of all one-million-year-old stars were found to have excess infrared emission. In a 1994 paper, John Stauffer of the Harvard-Smithsonian Center for Astrophysics and his colleagues reported that an

Disks can form around binary stars as well as single stars. A visible-light image (left) shows a single large disk surrounding the two stars of GG Tauri. A radio image (right) shows that the two members of L1551 IRS5 each have their own disk. The disks are about one million years old.



Claude Roddier (University of Hawaii/IFA), et al.

Luis Rodriguez (Instituto de Astronomia UNAM), et al.



100 MILLION YEARS

VISIBLE LIGHT

500 MILLION YEARS

RADIO WAVES

Al Schultz (CSC/STScI), Cherie Miskey (IACS/CUA), et al., and NASA

Wayne Holland, Jane Greaves (Joint Astronomy Centre), et al.

Older disks have virtually no gas, and the remaining dust is confined to the outer regions. The central part of both of these disks is clear, suggesting planetary systems have formed. The Beta Pictoris disk (left) is seen edge-on, while the Epsilon Eridani disk (right) is almost face-on.

even higher fraction of the young stars in the center of the Orion Nebula — perhaps 70 to 80 percent — showed signs of disks. Recent, more sensitive observations by the Infrared Space Observatory satellite confirm these findings.

Hubble has imaged disks around very young stars in Orion and Taurus both in the optical, with the WFPC2 instrument, and in the near-infrared, using the recently installed NICMOS infrared camera. Disks are viewed at many different angles, ranging from edge-on to nearly face-on, and are typically a few hundred astronomical units (AU) across. (One AU is the average distance between the sun and Earth, roughly 93 million miles or 150 million kilometers.) Two spectacular edge-on disks, one around the Orion star HH30 and the other around the "Butterfly Star" in Taurus, clearly show that circumstellar disks are fairly thin in their central regions and gently flare at distances of about 100 AU. Harvard-Smithsonian astronomers Lee Hartmann and Scott Kenyon predicted more than a decade ago that the parent star's heat would elevate disk material above and below a disk plane, making disks appear flared.

Astronomers estimate the mass of young circumstellar disks such as those in Orion to range from about one to ten percent of the sun's mass. That is more than ten times the mass needed to make a planetary system like ours. Dust accounts for about one percent of the mass, while the remaining 99 percent is mostly hydrogen and helium gas. It's the dust that emits virtually all of the infrared light. But radio telescopes can map the gas by observing the emission of a particular molecule, carbon monoxide being a favorite.

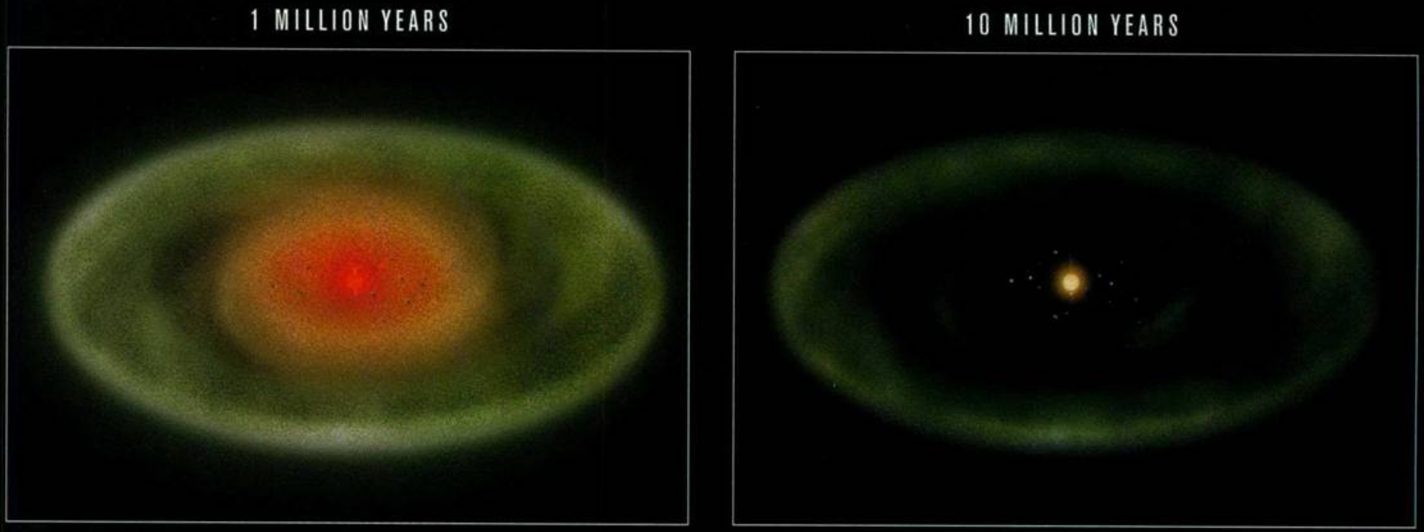
Stars are often born in pairs or multiple systems. What kind of disks do young binary stars have? Recent high-resolution images of the young binary GG Tauri, obtained with an adaptive optics system on the 3.6-meter Canada-France-Hawaii Telescope, reveal a large disk that surrounds both stars, a circumbinary disk. Luis Rodriguez of the Autonomous National University of Mexico and his colleagues have produced a radio map of another binary, L1551 IRS5, with the Very Large Array. The two stars, which are separated by a mere 45 AU, have truncated each other's disks: Each disk is barely 10 AU in radius. That confirms that disks in closely separated binaries probably evolve very differently than disks around single stars or binaries in which the two stars are far apart. What kind of planetary systems binaries form, if any, remains an open question.

BUILDING PLANETS

The Orion disks surround young stars still in the process of gravitationally contracting, and the disks themselves haven't been in existence long enough to form planets. How do these disks evolve? What happens to them after 10 million, 100 million, or even a billion years? The generally accepted theory is that they make planetary systems, roughly at an age of 10 million years. First the dust grains stick to one another to make things as big as pebbles. The pebbles then collide and stick together to build planetesimals.

George Wetherill at the Carnegie Institution of Washington and others have performed computer simulations to find out how that happens. Unfortunately, the simulations show it's difficult to build planetesimals from small pebbles; their gravity is too weak to attract other pebbles, and even if pebbles hit one another, they may not stick together very well (Krazy Glue wasn't around back then). So it remains a bit of a mystery how the planetesimals form in the first place (see "From Pebbles to Planets," February 1998).

But once planetesimals build up, the rest is easier to explain. Larger planetesimals have enough gravity to hold onto almost any object they collide with and to reign extra stuff in, so they grow bigger and bigger. Smaller planetesimals stick to big ones or get stomped to dust in collisions. In this way, a planetesimal can grow as big as the moon in about 100,000 years. Within several million years, rocky planets like Mercury, Venus, Earth, and Mars would have pretty much finished building up.



1 MILLION YEARS

10 MILLION YEARS

One-million-year-old disks contain 99 percent gas and one percent dust. As the disk ages, planets begin forming in the central regions, clearing gaps near the star. By 10 million years, most of the gas is gone, and either planets or planetesimals have already formed.

But for giant planets like Jupiter and Saturn, there is still a long way to go. Far from the parent star, it is cold enough for ice to form in the disk. The presence of ice means a lot more solid material is available for planet building. Scientists believe that giant planets start with 10-Earth-mass cores of rock and ice and then sweep up large quantities of gas to form thick atmospheres.

But it isn't easy to collect that much gas. Some computer models show it can take several million years for a planet to gather all that gas. That worries some astronomers. Can planets collect enough gas before the young star's powerful wind blows it all away? Could giant planets form in a completely different manner from the smaller rocky planets? Astronomers don't have all the answers yet, but finding disks around stars at different stages of evolution could be the key that answers these questions.

As large bodies build up in orbit around a star, they should sweep up just about all the available gas and dust and create a cavity in the center of the disk. In fact, in the 1980s, the Infrared Astronomical Satellite (IRAS) detected signatures of such disks. They had formed around a dozen or so mature, nearby stars, with ages of hundreds of millions of years. Unlike the very young stars, the older stars did not have any excess disk emission at near-infrared wavelengths, but they showed considerable excesses at longer wavelengths in the mid- and far-infrared. Dust in the inner part of a disk (within a few AU of the star) would be hotter and would emit mostly in the near-infrared, while dust at larger distances from the star would be cooler and radiate at the longer far-infrared wavelengths. So the lack of near-infrared emission in mature stars implies that their disks had developed central holes, probably because planets had already formed inside.

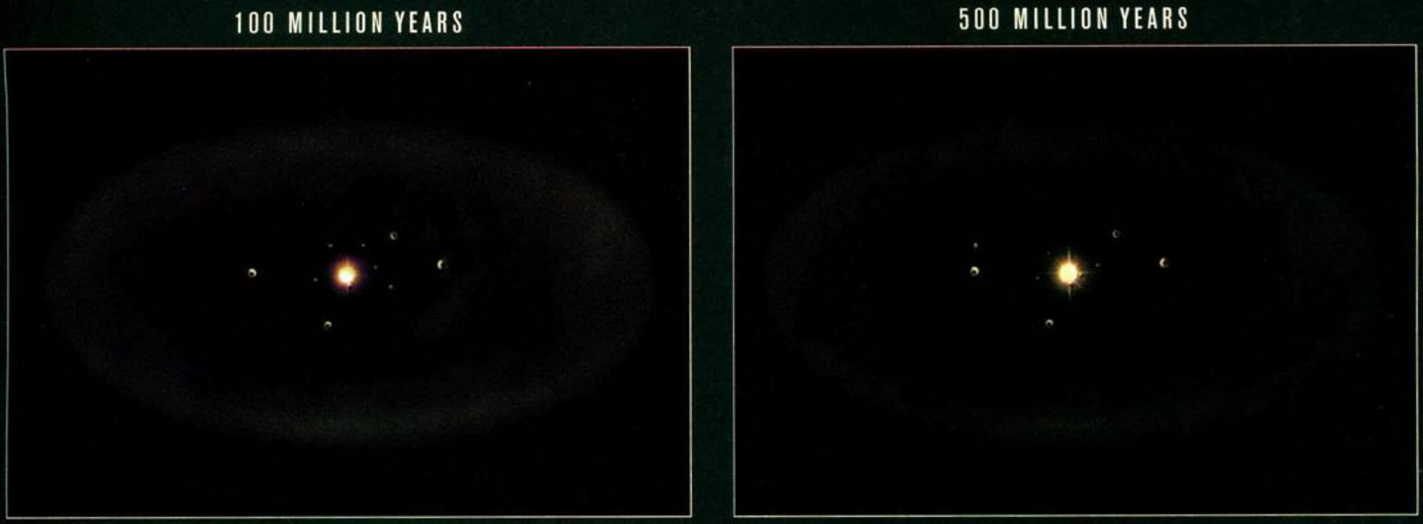
The big breakthrough in the study of older disks came in 1983 when Bradford Smith of the University of Arizona and Richard Terrile of the Jet Propulsion Laboratory imaged a disk around Beta Pictoris, a nearby star (63 light-years away) estimated to be roughly 100 million years old. Their image, which captured the visible light scattered by dust particles in the disk, provided the first direct look at a disk around a mature star, one that may host a newly formed planetary system. Unlike the Orion disks, the Beta Pictoris disk has only a tiny amount of gas; almost all the original gas has been either swept out by the star's wind or accreted by planets. The disk is a debris disk: The gas and dust probably come from comet and asteroid collisions after planet formation has already taken place. Since its discovery, more than 100 papers have been published on the Beta Pictoris disk, some reporting observations at wavelengths ranging from ultraviolet to radio, others modeling it as a cloud of cometary debris.

Do planets orbit Beta Pictoris? Nobody knows for sure, but Hubble Space Telescope observations of the Beta Pictoris disk show evidence of an inner hole. A recent Hubble image taken with the Space Telescope Imaging Spectrograph even reveals a slight twist in the disk that perhaps was caused by the gravity of a giant planet.

MATURE DISKS

Of the dozens of disks suspected to surround dozens of nearby mature stars, only that of Beta Pictoris had been imaged until early this year. But with the advent of sensitive new cameras capable of making high-resolution images at mid-infrared and millimeter wavelengths, astronomers have made a whole slew of new discoveries.

Last April, two groups announced the independent discovery of a nearly edge-on disk around a 10-million-year-old star named HR 4796A. I led one of the groups, which included astronomers from the Harvard-Smithsonian Center for Astrophysics and the University of Florida. The other group was led by David Koerner of the University of Pennsylvania. Because a 10-million-year-old disk is at just the right age to be forming planets, we were intrigued to see evidence in mid-infrared images of an inner hole with a size comparable to our own solar



As disks age, mature planetary systems form within 30 AU of the central star and virtually all the gas disappears. In the outer reaches, where the Kuiper belt resides in our solar system, collisions between asteroids and comets generate small amounts of dust.

Astronomy: Elisabeth Rowan

system. What's more, HR 4796A is a member of a binary system with a companion star 500 AU away (about 13 times the average Pluto-sun distance). This discovery confirms that disks in binaries can survive long enough to make planets, provided that the two stars are widely separated.

The amount of dust in this disk adds up to only one Earth mass, and there may be six to seven Earth masses worth of gas, according to Jane Greaves of the Joint Astronomy Centre (JAC) in Hawaii. That is about 1,000 times less total mass than the amount in the Orion disks. Presumably, the original gas and dust has gone somewhere, perhaps into bigger bodies such as planets. We don't actually see any planets around HR 4796A, just circumstantial evidence in the form of an inner disk hole and a paucity of gas and dust.

That same week, a team of astronomers led by JAC's Wayne Holland released radio images of disks around three other mature stars — Vega, Fomalhaut, and Beta Pictoris itself. All three stars are older than HR 4796A, with ages of a few hundred million years. So they must be well past the main epoch of planet formation. Interestingly, the images, obtained with a revolutionary new millimeter-wave detector named SCUBA on the 15-meter James Clerk Maxwell Telescope on Mauna Kea, show mysterious giant blobs in the disks of Vega and Beta Pictoris that could be cold dust trapped in orbit around giant planets. The blobs are far from their stars (80 and 400 AU, respectively); standard models can't explain how planets could form at such large distances.

Just last July, Greaves and Holland's team unveiled a stunning image of a face-on dust disk around the solar-type star Epsilon Eridani. With a distance of only 10 light-years, Epsilon Eridani is one of the sun's closest stellar neighbors. The image clearly shows a central cavity as well as a bright spot in the ring which the discoverers say could be dust in orbit around a planet. The dust ring itself is at about the same distance from the parent star as the Kuiper belt of comets is from the sun. Given Epsilon Eridani's estimated age of 500 million to one billion years, we're probably seeing dust debris left over from collisions between asteroids or comets. Again, no planets have been detected yet, but the disk shows strong evidence of planet-building activity.

Recent observations of the solar-type star Rho^1 Cancri bolster the disk-planet connection. San Francisco State University astronomers Geoff Marcy and Paul Butler discovered two years ago that this star is wobbling due to the presence of at least one, and possibly two, giant planets. Last January Carsten Dominik of Leiden Observatory in the Netherlands and his colleagues reported that the Infrared Space Observatory had detected excess infrared emission, indicative of a disk, from Rho^1 Cancri. Recently, David Trilling and Robert Brown of the University of Arizona reported that they had actually imaged the disk by blocking out the light from the central star.

With the new infrared and millimeter instruments, astronomers are finally peering into planetary nurseries and seeing them at different stages of evolution. We are zeroing in on the moment of planetary birth. Now the race is on, as different groups of astronomers compete for precious observing time on big telescopes with the best instruments to look at the most promising targets. We will soon have a "disk census" for the nearby stars and a good guess at how common planet-forming disks are. We will also learn how long it takes for dust disks to turn into full-blown planetary systems, and we will catch them at different stages of the process. Given the variety of stars and their environments, we are likely to find a diversity of planetary nurseries and toddlers. Astronomers have not directly seen how the planets assemble in these disks. But we have come tantalizingly close.

Contributing editor Ray Jayawardhana is studying star formation and circumstellar disks for his Ph.D. thesis at Harvard University. His previous feature for Astronomy *was "Deconstructing the Moon" in the September issue.*

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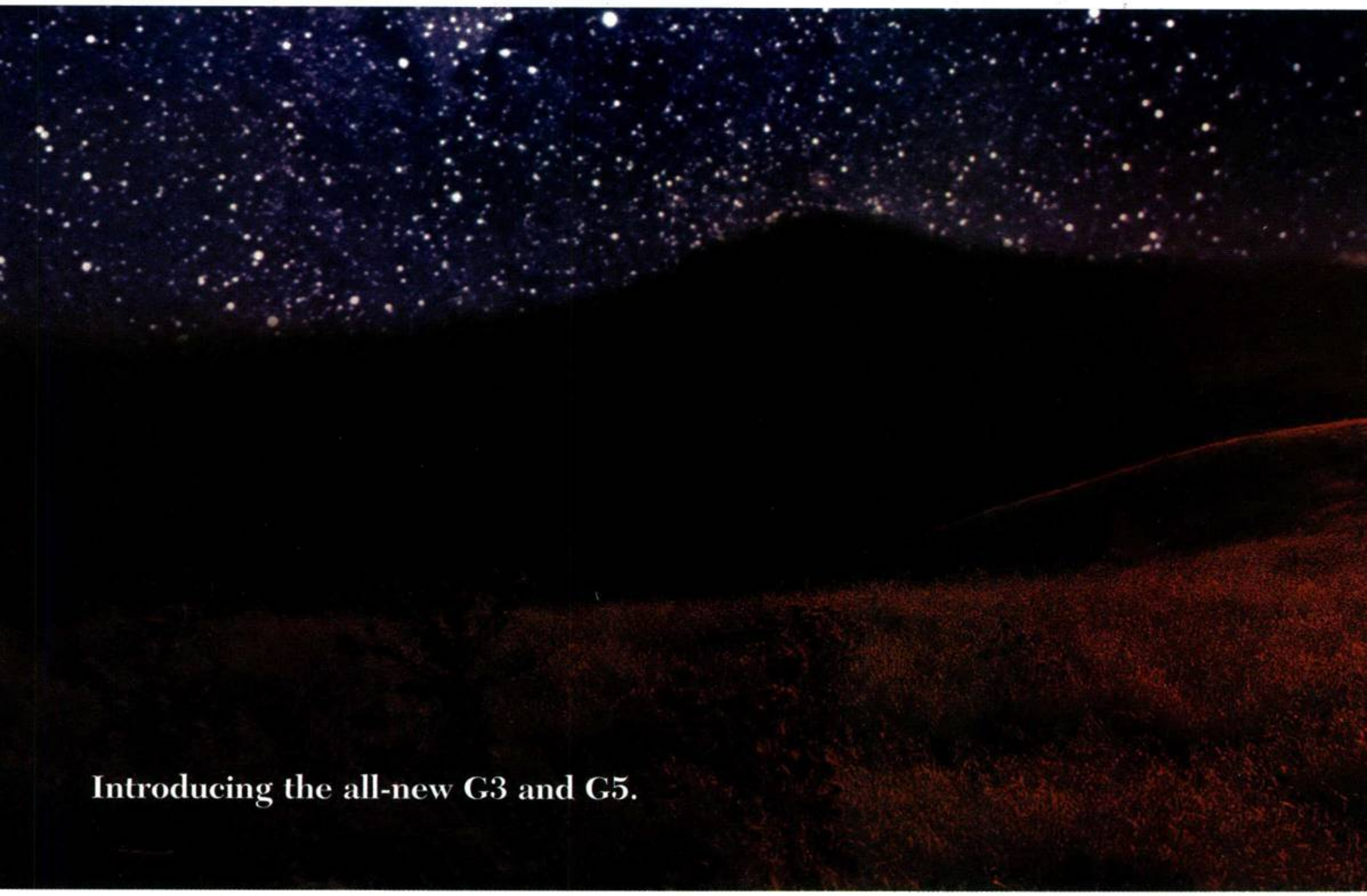

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CELESTAR 8

- An economical but full featured 8" Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8 to offer the **lowest price ever** on a Celestron fork mounted 8" with so many features.
- No sacrifice was made in the optics. The unsurpassed superior quality Celestron hand-figured system delivers diffraction-limited optics. Starbright® coatings are standard.
- The electronics are DC for easy astronomy on the go.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows for fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the *Sky & Telescope* review — "the digital electronics delivered a near-perfect sidereal tracking rate."
- The Celestar 8 is powered by a 9 volt alkaline battery.
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90°.
- The new and unique Wedgpod is a combination tripod and wedge. It has a fixed height (33") and is lightweight without compromising its stability.
- Made in the U.S.A.
- Standard accessories included: 6x30 Finderscope, Star Diagonal – 1-1/4" and a 25mm SMA Eyepiece – 1-1/4" (81x).

CELESTAR 8 DELUXE

- This telescope utilizes the same superior optics used in all of Celestron's 8" Schmidt-Cassegrain telescopes and has all of the features of the Celestar 8, but is enhanced, for those who prefer a premium version of the spectacular Celestar 8.
- This model has a heavier duty fork mount and drive base, with a precision worm gear drive system.
- Superior tracking accuracy is attained with this drive system, which has four tracking rates and PEC (Periodic Error Correction).
- For the kind of versatility that makes observing a pleasure, the hand controller makes available a micro guide rate of .5x sidereal and a slew rate of 8x sidereal.
- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging.
- The standard accessories for this telescope include: a Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod that's exceptionally rigid and sturdy, with adjustable height.
- Also standard is a large 9x50 Finderscope, and a multi-coated 26mm Plössl Eyepiece – 1-1/4" (78X).

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ADVANCED ASTRO MASTER®

The Celestar 8 Computerized and the Celestar 8 Deluxe Computerized telescopes are the same as the Celestar 8 and Celestar 8 Deluxe but with the addition of a factory **installed** and **tested** Advanced Astro Master®.

The pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9 volt battery.

Contains an RS-232 serial interface to enable usage with PC programs like "The Sky"™ by Software Bisque.

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ULTRA PORTABILITY

C5+ shown with
optional hand control

C5+

- For astronomy on the go, the C5+ can't be beat. Due to its excellent Schmidt-Cassegrain design and careful crafting, this telescope is a serious, high performance instrument, and its compact size makes it totally portable.
- The optical system of the C5+ features Starbright® coatings. An *Astronomy* magazine review said, "the C5 I tested contained superb optics. At high powers, stars exhibited a clearly defined Airy disk surrounded by a bright first diffraction ring and several successively fainter outer rings. This was a telescope that demonstrated how well Schmidt-Cassegrain optics can perform and met Celestron's promise of diffraction limited optics."
- The C5+ features Celestron's legendary hand-figured, diffraction limited optical system for optical performance you can depend on. The reputation for excellence of this telescope is such that it was chosen by NASA, over all other competitive models, for several space shuttle missions.
- The DC electronics of the C5+ have a built-in drive controller, powered by a 9 volt alkaline battery. A comment from the *Sky & Telescope* review — "the digital electronics delivered a near perfect sidereal tracking rate."
- Standard equatorial wedge supplied with the C5+ has a built-in bubble level and is adjustable from 0° to 90°.

STANDARD SPECIFICATIONS:

- 5" (127mm) Aperture
- Focal Length of 1250mm
- Focal Ratio of f/10
- Standard 1¼" Accessories Include: 25mm SMA Eyepiece (50x), Star Diagonal, and Visual Back
- 6x30 Finderscope
- Unique Single-Arm Fork Mount with Carrying Handle
- Weight: 23 lbs. (including the wedge)
- Made in the U.S.A.

- The C5+ can even be converted to a computerized telescope with optional accessories.

ULTIMA® 9¼ and ULTIMA® 11

- The compact Schmidt-Cassegrain design makes these powerful telescopes portable enough to load in your car and take out to your favorite observing sites. Further, this design is user-friendly, so even a beginner can enjoy using a large telescope.
- The images captured by these versatile telescopes are superb, due to optics designed to perform flawlessly.
- 9¼" (235mm) Aperture, 11" (279mm) Aperture
- 9¼" Focal Length of 2350mm, 11" Focal Length of 2800mm
- Focal Ratio of f/10
- Starbright® Coatings
- 6x30 Finderscope – 9¼", 7x50–11"
- Hand Controller
- Focusing Micrometer on 9¼"
- PEC Electronics
- Ergonomic, user-friendly operation is the trademark of the Ultima® telescopes. The Ultima 9¼ and 11 telescopes were designed with functional use as a top priority, and they deliver.
- Standard 1¼" Accessories Include: 25mm SMA Eyepiece (94x) and Star Diagonal, 26mm Plössl (108x) for 11"
- Adjustable, Rigid Metal Tripod, Heavy Duty Wedge and Deluxe Latitude Adjuster.
- Weight: 74 lbs. for 9¼", 80 lbs for 11"
- Made in the U.S.A.
- The superb optics use high transmission Starbright® coatings to capture the brightest, sharpest images.
- The newly designed fork tines of the mount and drive base are sand cast and they add greater stability.
- The totally cordless DC servo quartz drive system runs on an ordinary 9 volt battery.
- Celestron's optional Advanced Astro Master® can be added to create a computerized telescope.

ULTIMA® 11

ULTIMA® 9¼

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THE SKY SHOW

This month offers sky watchers a chance to see nature's fireworks as the meteor showers of November put on their show. by Martin Ratcliffe and Alister Ling

▶ November illustrates that good things do come in groups of three. The month opens with the Taurid meteor shower. On the nights of November 3 through 13, up to ten meteors per hour might be seen emanating from the region between the Hyades and Pleiades star clusters in Taurus, the Bull. The Taurids are caused by debris from the shortest period comet known, Comet Encke. Its orbit takes it around the sun once every 3.3 years.

Later in the month the Leonids reach their long-awaited 1998 peak. This shower is associated with Comet Tempel-Tuttle, which has an orbital period of 33 years. Observers have been waiting with bated breath for this shower and its expected storm on November 17. In 1966, a tremendous storm of thousands of meteors per hour lit up American skies, a repeat of the 1833 event. Hopes have been high for 1999, but recent calculations by Don Yeomans at NASA's Jet Propulsion Laboratory indicate that perhaps a significant storm could happen this year. (For further details, see "Leo's Incandescent Rain," page 84.)

Stretching the number three thread to its final apogee, the three stars in the belt of Orion rise over the eastern horizon by 11 p.m. in early November. They appear to be pointing to the red star, Aldebaran. This ruddy 0.9-magnitude eye of the celestial Bull lies at one point of the V-shaped group of stars called the Hyades. As we see Orion in the sky, it appears to be rising to meet the challenge of the charging bull — a challenge that, according to the Roman author Manilius, Orion should have no problem handling. Unfortunately, this meeting of two great winter sky characters is not recalled in any of the ancient sky legends.

By the end of November, the belt stars of Orion are

Orion the Hunter rises above the rocks as a waning crescent moon and Mars, in Gemini the Twins, cast a soft glow over Nevada's Valley of Fire State Park.

Jerry Schad

NOVEMBER 1998

3 The moon passes 1.7° south of Saturn, 4 a.m. EST
The moon is at perigee (221,590 miles from Earth), 7:40 p.m. EST

4 Full moon is at 12:18 a.m. EST

5 The moon passes 0.6° north of Aldebaran, 9 p.m. EST

9 Mercury passes 1.9° north of Antares, 4 a.m. EST

10 Asteroid Eunomia is at opposition, 10 a.m. EST (page 79)
Last quarter moon is at 7:28 p.m. EST

11 Mercury is at greatest eastern elongation (23°), 4 a.m. EST (page 78)
The moon passes 0.3° south of Regulus, 5 p.m. EST

13 The moon passes 0.5° north of Mars, 1 p.m. EST (page 81)

14 Asteroid Ganymed is at opposition, 7 p.m. EST

17 The moon is at apogee (252,583 miles from Earth), 1:26 a.m. EST
Leonid meteor shower peaks

18 New moon is at 11:27 p.m. EST

21 Comet Giacobini-Zinner is at perihelion (96.1 million miles from the sun), 3 a.m. EST (page 78)

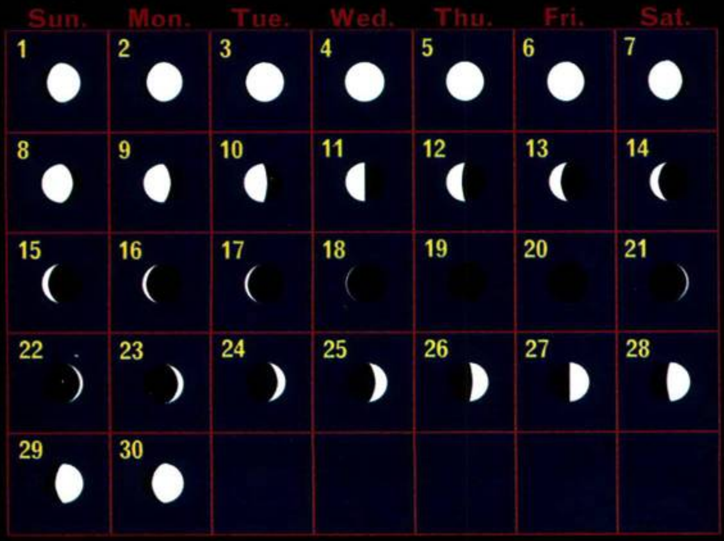
24 The moon passes 1.9° north of Neptune, 4 a.m. EST
The moon passes 2° north of Uranus, 10 p.m. EST

26 First quarter moon is at 7:23 p.m. EST

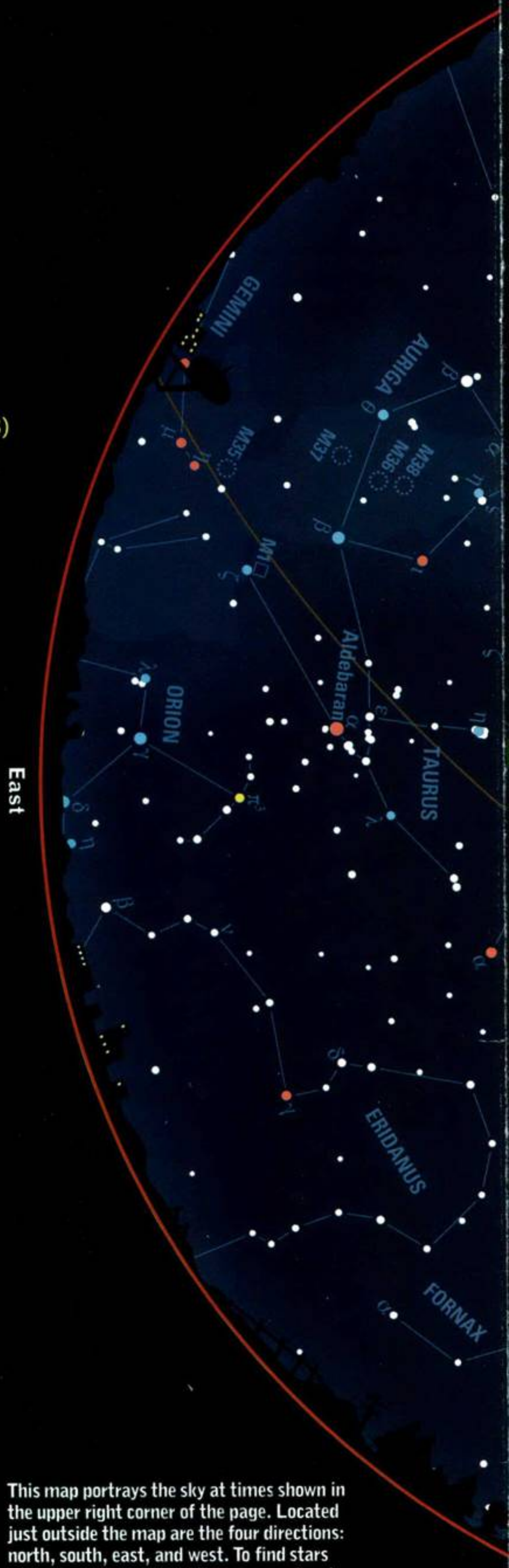
27 The moon passes 0.6° south of Jupiter, 8 p.m. EST

28 Asteroid Ceres is at opposition, 5 p.m. EST

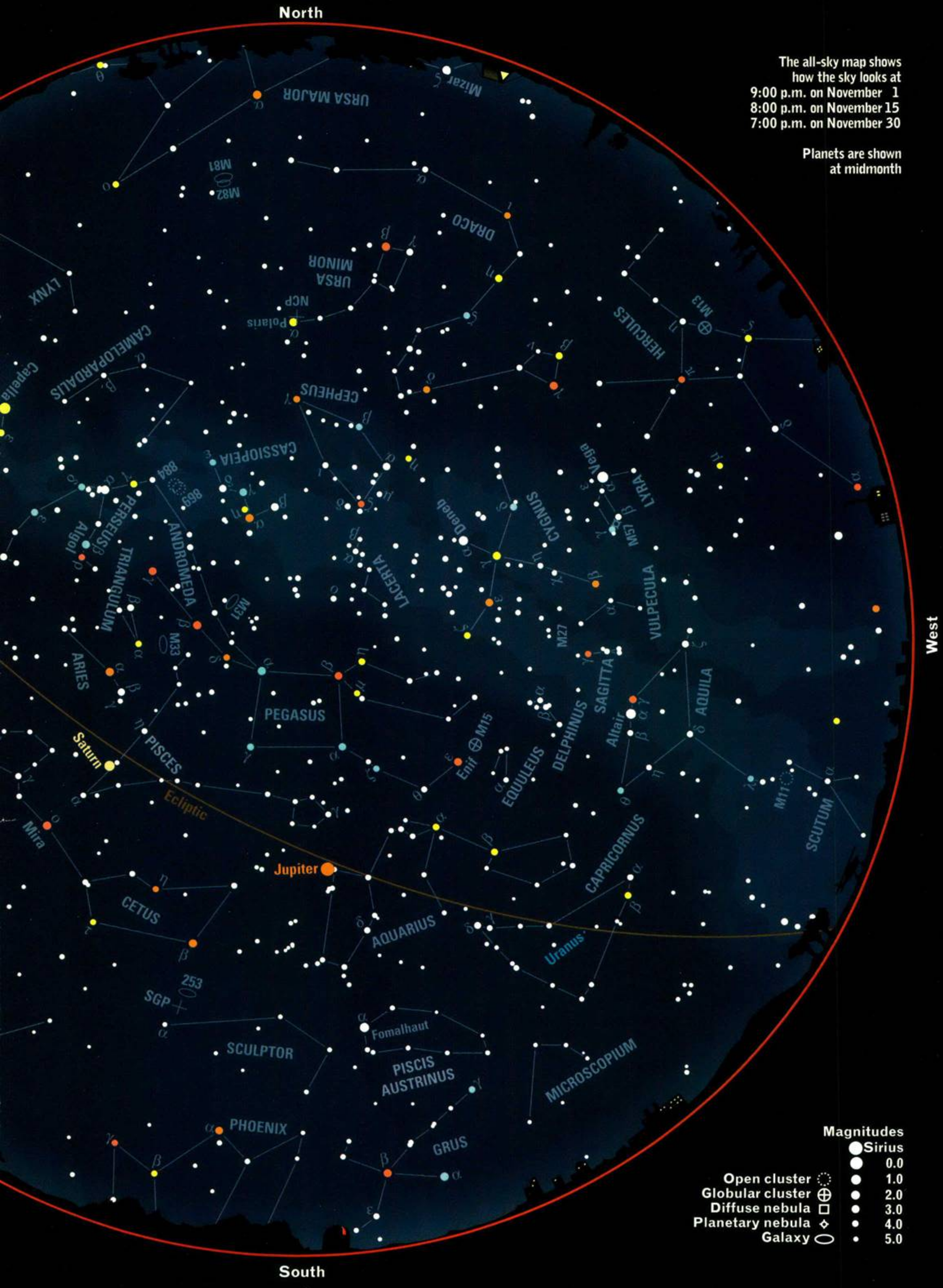
30 Pluto is in conjunction with the sun,. 3 a.m. EST
The moon passes 1.8° south of Saturn, noon EST



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					



This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

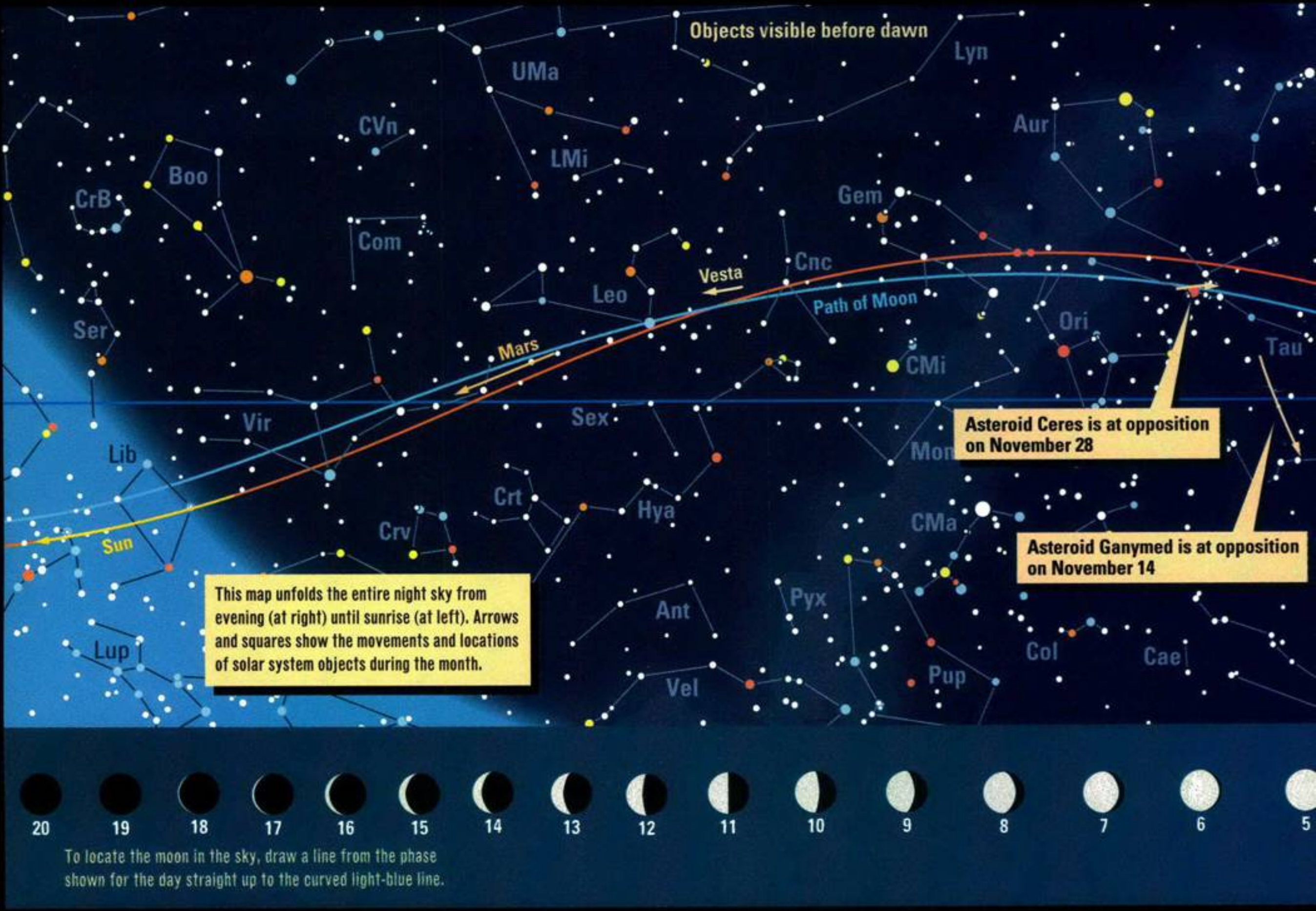


North
URSA MAJOR
Mizar
M81
M82
DRACO
URSA MINOR
NCP
Polaris
LYNX
CAMELOPARDALIS
Capella
CEPHEUS
CASSIOPEIA
HERCULES
M13
LYRA
Vega
M57
CYGNUS
Deneb
884
869
PERSEUS
Algol
TRIANGULUM
ANDROMEDA
M31
M33
LACERTA
VULPECULA
M27
SAGITTA
ARIES
PEGASUS
DELPHINUS
AQUILA
Altair
EQUULEUS
M15
Enif
SCUTUM
M11
Saturn
PISCES
Ecliptic
Mira
Jupiter
CETUS
AQUARIUS
CAPRICORNUS
Uranus
253
SGP
SCULPTOR
Fomalhaut
PISCIS AUSTRINUS
MICROSCOPIUM
PHOENIX
GRUS
West
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
9:00 p.m. on November 1
8:00 p.m. on November 15
7:00 p.m. on November 30

Planets are shown
at midmonth

THE PATH OF THE PLANETS


Objects visible before dawn
Lyn
UMa
CVn
LMi
Aur
Boo
CrB
Com
Gem
Cnc
Vesta
Leo
Path of Moon
Ser
Mars
Ori
CMi
Tau
Vir
Sex
Lib
Mon
Crt
Hya
CMa
Sun
Crv
Pyx
Ant
Col
Cae
Lup
Vel
Pup
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

Asteroid Ceres is at opposition on November 28

Asteroid Ganymed is at opposition on November 14

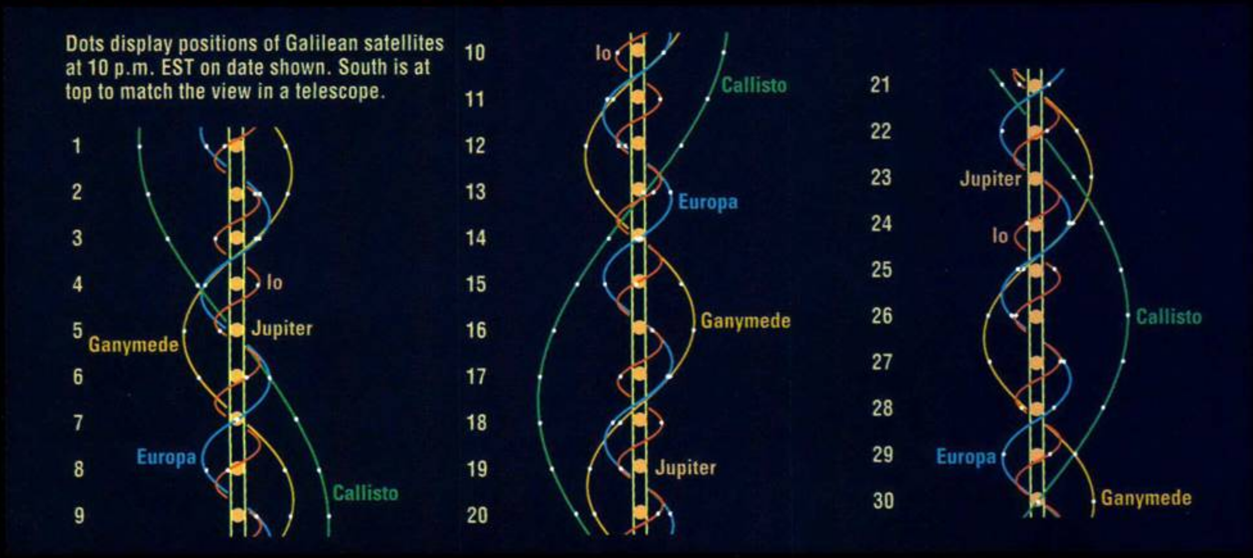
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

10"

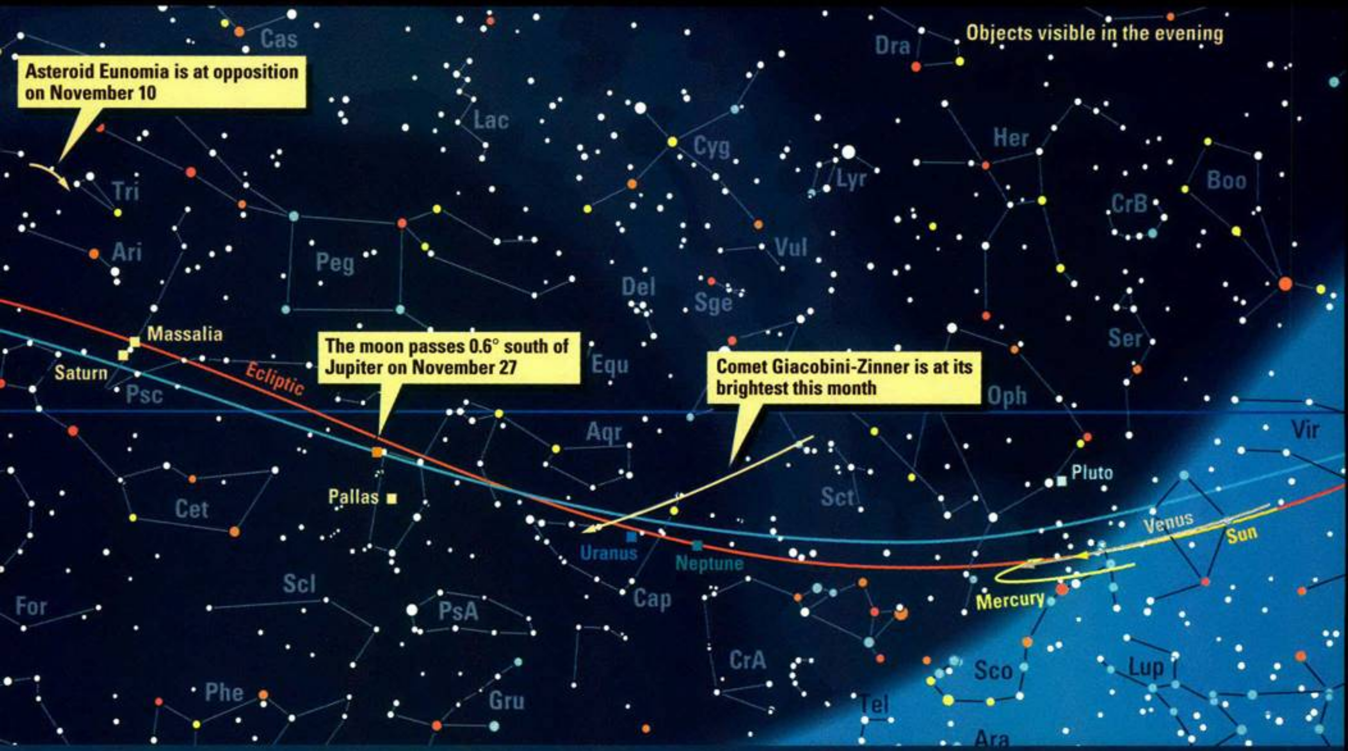
S
W — E
N

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	November 1	November 15	November 15	November 15	November 15
Magnitude	−0.2	−0.1	−3.9	1.5	−2.6
Angular Size	5.6"	7.1"	9.8"	4.9"	44.3"
Illumination	81%	54%	100%	93%	99%
Distance (AU) from Earth	1.200	0.943	1.709	1.928	4.450
Distance (AU) from Sun	0.447	0.380	0.725	1.661	4.961
Right Ascension (2000.0)	15h45.5m	16h52.8m	15h36.8m	11h36.6m	23h18.8m
Declination (2000.0)	−22°14'	−25°10'	−19°00'	4°16'	−5°59'

JUPITER'S MOONS



Dots display positions of Galilean satellites at 10 p.m. EST on date shown. South is at top to match the view in a telescope.

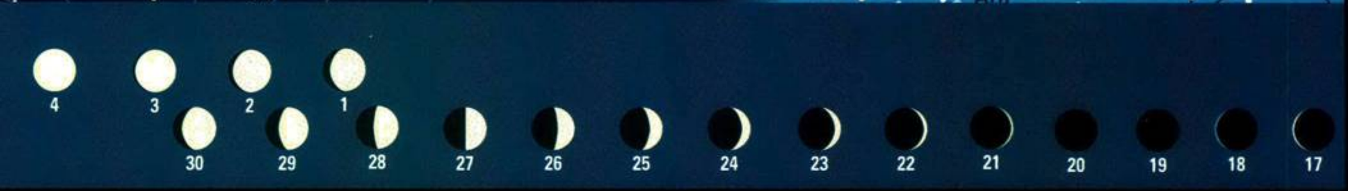

Cas
Lac
Cyg
Lyr
Dra
Her
CrB
Boo
Tri
Ari
Peg
Vul
Del
Sge
Ser
Massalia
Saturn
Psc
Ecliptic
Equ
Oph
Vir
Aqr
Pluto
Cet
Pallas
Sct
Venus
Sun
Uranus
Neptune
Mercury
For
Scl
PsA
Cap
CrA
Sco
Lup
Phe
Gru
Tel
Ara

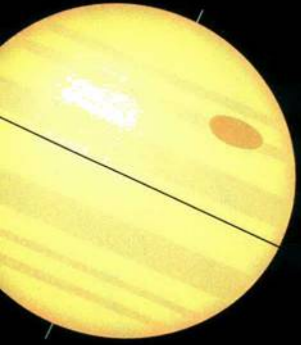
Objects visible in the evening

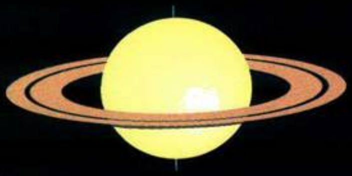
Asteroid Eunomia is at opposition on November 10

The moon passes 0.6° south of Jupiter on November 27

Comet Giacobini-Zinner is at its brightest this month

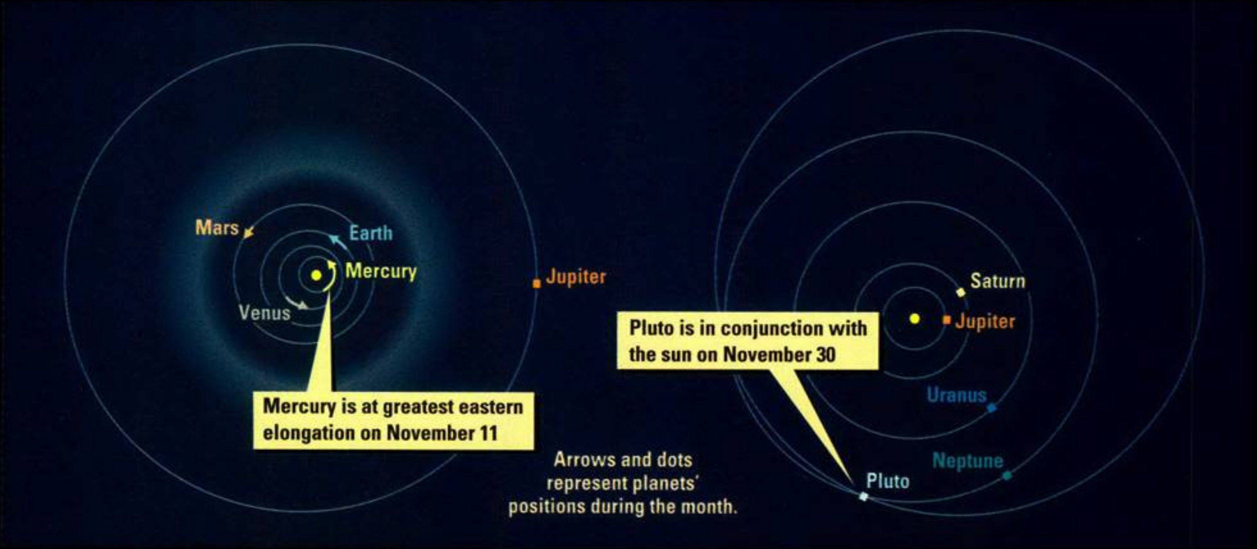

4
3
2
1
30
29
28
27
26
25
24
23
22
21
20
19
18
17





SATURN	URANUS	NEPTUNE	PLUTO
November 15	November 15	November 15	November 15
−0.1	5.8	7.9	13.9
19.9"	3.5"	2.2"	0.1"
100%	100%	100%	100%
8.370	20.085	30.503	31.044
9.282	19.881	30.135	30.109
1h49.8m	20h47.0m	20h07.3m	16h29.7m
8°23'	−18°36'	−19°54'	−10°17'

THE PLANETS IN THEIR ORBITS


Mars
Earth
Mercury
Jupiter
Venus
Saturn
Jupiter
Uranus
Neptune
Pluto

Mercury is at greatest eastern elongation on November 11

Pluto is in conjunction with the sun on November 30

Arrows and dots represent planets' positions during the month.

FIRST VIEW: The Great Andromeda Galaxy

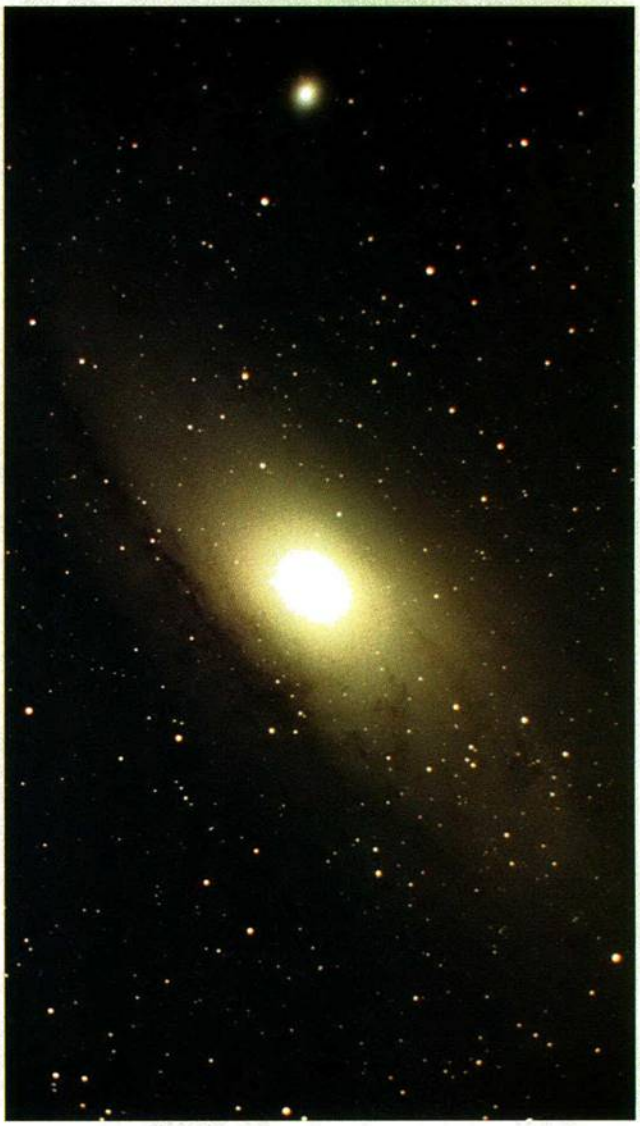
Most adults have heard of the Andromeda Galaxy (M31), but few realize that they can see it with their eyes alone. New data from the Hipparcos satellite has set our neighbor's distance at 2.9 million light-years.

For most amateurs, M31 is one of the first few deep-sky objects they see — for good reason. At magnitude 3.5, the Andromeda Galaxy is bright enough to see under city skies. Start at Beta (β) Andromedae (the middle star of the three in Andromeda's broad arc), from there go 4° northwest to Mu (μ) Andromedae. The galaxy can be found along a line that extends from Beta past Mu. The two stars and galaxy are all nearly equidistant from one another along a straight line.

With binoculars, M31's elongated form is obvious, and the farther you are away from city lights, the greater its length appears. In dark skies, the galaxy spans easily one-half the field of view in a pair of 7x50 binoculars. In town, the view through a telescope appears to be little more than a gray oval that appears brighter in the middle.

Many first-time observers have a hard time seeing M31 because they are looking for an object with spiral structure. One aid to the novice observer comes by centering the scope on M31's diminutive companion, M32, just to the south. Though small, its surface brightness is considerably higher than M31 — if you plan it right, the large glow of M31 will be visible toward the edge of the eyepiece. Compare the sizes of these two galaxies — you'll be impressed.

Under dark skies, M31 takes on a fresh appearance. The outer glow is quite large. If you look closely, you can see that the northern edge is sharply outlined in contrast to the smooth drop off of light on the M32 side. That sharp edge is the first dust lane. With a telescope, a fainter band of light can be found outside the dust lane while large scopes reveal a second dust lane. Not to be missed from dark country skies is a brighter blob in Andromeda's halo — the star cloud NGC 206. Slide to the southwest along the dust lane's edge to find it.



Jim Heaton

well above the horizon by 9 p.m. They are joined two hours later by the guard dogs that follow Orion across the sky. One of these canines is marked by bright Sirius, the Dog Star. It is the brightest star in the sky shining at magnitude –1.5. It resides in the constellation Canis Major, the Great Dog. Rising 15x20 minutes before Sirius is the constellation Canis Minor, the Little Dog. Its principal star is 0.4-magnitude Procyon.

Neither Sirius nor Procyon competes with the brilliance of **Jupiter**. This large planet rests high in the south at sunset. As November opens, it shines at magnitude –2.7 — more than double the brilliance of Sirius. Jupiter is visible for the entire evening in the constellation Aquarius, the Water Bearer, and sets well after midnight. Though two months past its opposition date, early evening observations of Jupiter high in the south will yield a spectacular view of its cloud features and four major moons. On November 27, an eight-day-old moon passes less than one moon diameter south of Jupiter in the early evening. It will be a lovely conjunction, so make time to go out and see it.

Point your telescope at the jovian atmosphere for a closer look at some major changes that occurred earlier this year. Two of the famous white ovals, designated BC and DE, appear to have merged into one giant white spot now called BE. This new feature is the largest atmospheric effect to have taken place on the planet since the impact of Comet Shoemaker-Levy 9 in 1994.

November's almost full moon passes about 4° southwest of **Saturn** on the evening of November 2. Watch throughout the night as the moon moves slowly toward the planet. It gets as close as 2° south of Saturn by dawn. Since the ringed planet has just passed opposition, it remains visible in the southeastern corner of Pisces nearly all night. It shines at magnitude –0.1 and fades only to magnitude 0.1 by month's end.

Mercury also makes an evening apparition in November, though in a poor position for Northern Hemisphere observers. The elusive planet lies very low in the southwest all month. Even at this poor angle, Mercury might be spotted in binoculars just 2° north of Antares on November 9. The planet's greatest eastern elongation occurs two days later when Mercury is 23° from the sun. Its altitude never reaches any great height, but right to this point Mercury maintains a respectable magnitude 0.0. Following its eastern elongation, Mercury begins to fade. By month's end the planet will be at magnitude 4.3. The crescent moon makes a fleeting appearance with Mercury, passing 7° north of the planet on November 20.

Our sister planet, **Venus**, is effectively out of sight on the far side of the sun. It past through superior conjunction at the end of October and will not emerge from the solar glare until December.

After the first week of November when the moon exits the evening sky, the stars of late fall take on a majestic appearance. The great arms of our Milky Way Galaxy stretch from west to east, passing just north of the zenith.

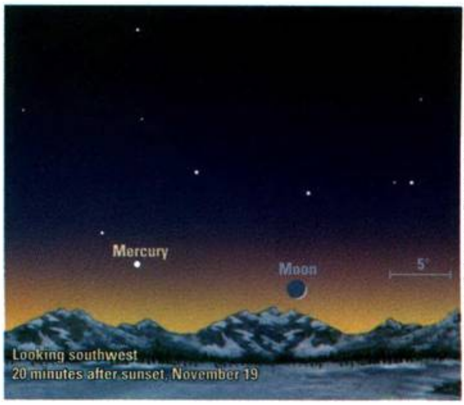
Resting high at the zenith around 9 p.m. is our companion, the Andromeda Galaxy. At magnitude 3.5, it's the farthest object that the unaided eye can see. Located in the constellation

Altitude Is Better Than Elongation

A quick glance at the numbers suggests that Mercury's maximum elongation of 23° from the sun is good news for observers. But by itself, this number can be misleading.

The shallow angle that Mercury's orbit makes with the Northern Hemisphere's western horizon during autumn evenings is a key factor in finding the planet. If you could tip the orbit straight up, Mercury would be a snap to find. But during this apparition, Mercury's orbital path appears to lie nearly along the horizon. Another problem is that the sky will still be bright by the time Mercury sets. You'll need binoculars to track down the diminutive magnitude 0 peach-colored dot. Orange Antares will be nearby, though invisible to most observers.

A 21-hour-old crescent moon will be close to Mercury on November 19, though the geometry also makes it hard to spot. For those living on the West Coast, it will be nearly impossible to find. Even the 45-hour-old moon the next evening will escape the notice of most casual observers.



All illustrations by *Astronomy:* Elisabeth Rowan

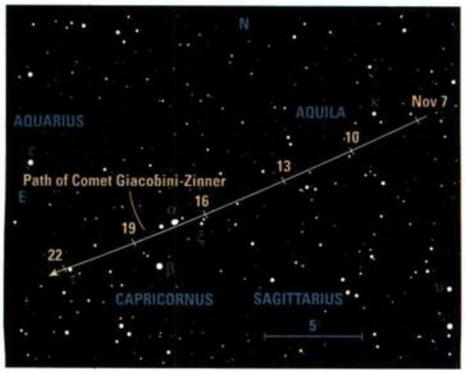
Comet Giacobini-Zinner

Thanks to the ever shorter day, Comet Giacobini-Zinner remains well-placed in the evening sky. Nevertheless, you'll have to plan your observations around the moon's schedule. At magnitude 9, the comet will be washed out by the full moon in the first days of the month.

By November 7, Giacobini-Zinner is 30° above the horizon when darkness arrives — more than an hour before moonrise. Look for a stubby dust tail pointing away from the sun to the east-northeast. Barely visible to most binocular users, Giacobini-Zinner should exhibit some detail in a telescope. Spend time moving from low power to high power and back again. As your eye and brain adjust to the image, you'll be able see more detail whatever the magnification. Giacobini-Zinner is well known for its unpredictable outbursts, so take time to check the inner coma for jet activity.

On the evening of November 17, the tail crosses in front of the delightful pair Alpha^1 (α^1) and Alpha^2 (α^2) Capricorni. The stars may fade when thicker dust jets get in the way. From November 23 on, the moon ruins the view for all but the CCD-imagers.

Tim Puckett



of Andromeda, this dim fuzzy blob of light (designated M31) lies 2.9 million light-years away. Through telescopes the two brightest companion galaxies to M31, called M32 and NGC 205, are quite easy to see. M31 lies 7°, or about one binocular field, to the northwest of the magnitude 2.1 star, Beta (β) Andromedae.

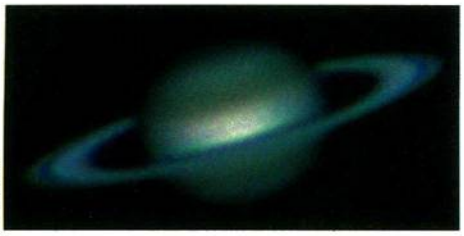
After you have found M31, try looking for M33. This spiral galaxy lies an equal distance to the southeast of Beta Andromedae in the constellation Triangulum. Its distance from us is similar to M31, but its orientation shows more of the galaxy's spiral structure. Its surface brightness is much lower than M31, and it can be disappointing in many telescopes. Binoculars will show the galaxy well, particularly if you mount them on a sturdy tripod.

While you are surveying Triangulum, try to find asteroid 15 Eunomia. The asteroid reaches opposition on November 10 and brushes NGC 890 on November 26. With its magnitude of 7.9, any small telescope can track the asteroid's path past the galaxy for a few days on either side of November 26.

Bright stars stud the Milky Way near the western and eastern horizons. To the northwest, the summer triangle is making its last appearance. Altair is the first to set, while Vega and Deneb swing very low to the north later in the evening.

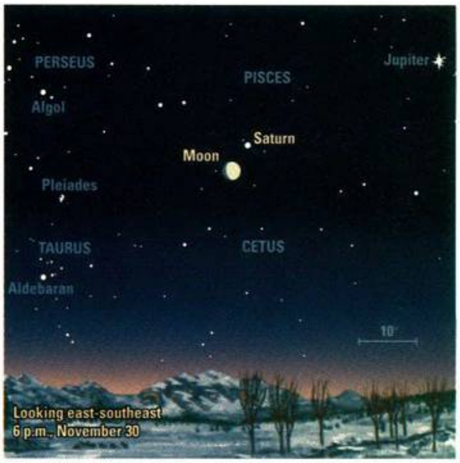
As the bright summer stars exit west, the jewels of winter rise on the opposite horizon. Taurus the Bull and Auriga the Charioteer lead the way — standing high in the east by 9 p.m. The two apparently reclining twins, represented by

Sociable Saturn


David Hanon

Despite the season's dropping temperatures, it's time to do some evening observing. The bright planets are putting on a display, and there is no better planet than Saturn to show off to neighbors or visitors at a public star party.

Now that Saturn has passed opposition, you will be able to pick out a thin, dark line along its eastern limb. This is the shadow of the cloud tops on the rings. If you're observing with a small scope, chances are the brightest "star" in the field is the giant moon Titan. Most observing handbooks have a chart for identifying all the bright moons. It's a good idea to have one of these books on hand while your observing. They offer a wealth of information within their pages.



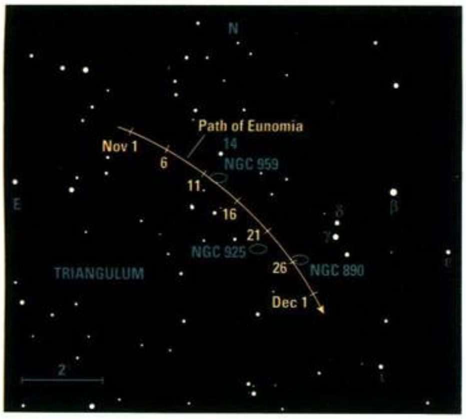
Looking east-southeast
6 p.m., November 30

An Asteroid in Galaxy Country

The asteroid 15 Eunomia (the 15th asteroid to be discovered) is parading brightly through Triangulum this month. This asteroid has a diameter of 170 miles (270 km) and was first spotted by the Italian astronomer A. de Gasparis on July 29, 1851.

The asteroid will reach opposition on November 10. In the process it will brighten to an easy magnitude 7.9 — suitable for binocular observing. To find the asteroid, use the bright stars of Triangulum and the map below.

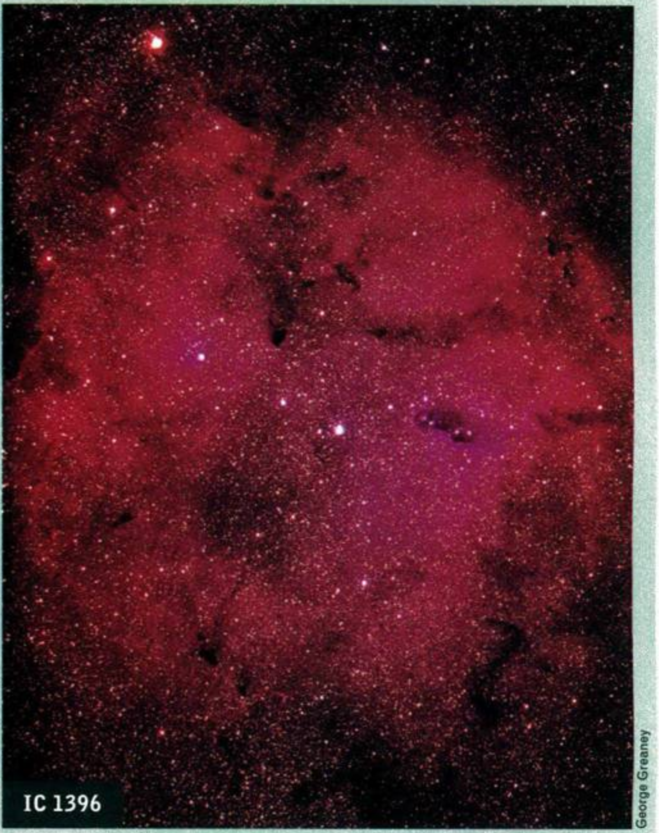
The map reveals Eunomia's path past some of Triangulum's galaxies, but you must get out to dark country skies with at least a 6-inch telescope to see them. On Friday night, November 13, the 12.4-magnitude galaxy NGC 959 will lie only 15' northwest of the interloper. Also look for NGC 925 at magnitude 10.1 and NGC 890 at magnitude 11.2. Both are attractive targets within a low-power field of view. Take a closer look at these galaxies toward month's end when 15 Eunomia passes by.



NGC 925

Preston Scott Justis

OBSERVER'S CHALLENGE: Dark Lanes in IC 1396

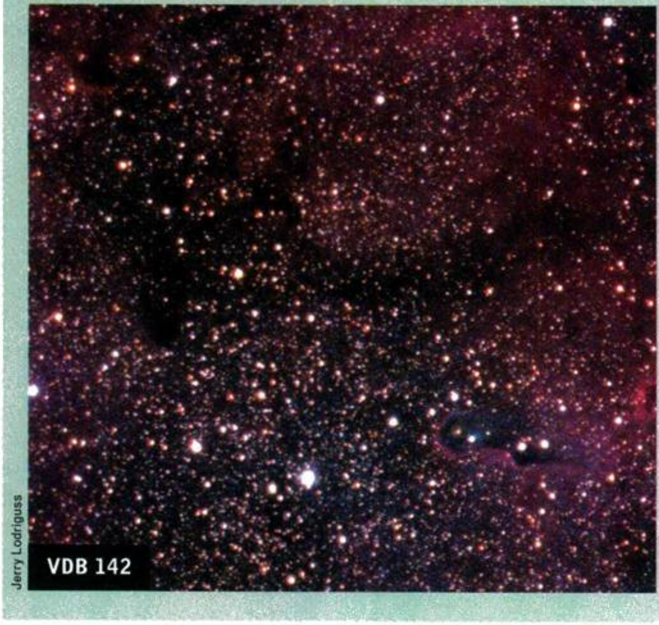

IC 1396

George Greaney

An object that E. E. Barnard discovered during his Milky Way photographic survey is this month's challenge. A gorgeous, large, emission nebula, IC 1396 requires only dark skies to be seen. Even if you don't know it by name, you'll have seen its picture.

Start your observations with a high-contrast nebula filter. IC 1396 is quite large (more than 2° across), and to see all of it requires very low power. I've been able to spot the fuzzy patch with a 14mm hand-held scope at a magnification of 2x (a camera lens with an adapter to hold an eyepiece). At the Mt. Kobau Star Party with a 4-inch Astroscan at a magnification of 16x, the entire cloud was visible. It appeared thicker along the three stars of the central region and up toward the bright, orange star Mu (μ) Cephei (nicknamed the Garnet Star by Sir William Herschel) though the area was awash in a sea of background stars from the Milky Way.

The most obvious dark lane is Lynds Dark Nebula (LDN) 1092 on the western edge. Halfway between this and the middle is the bright nebula van den Bergh 142. Though visible in many CCD pictures, it is a faint feature. Barnard B160 is the large black area on the southern edge of IC 1396. The backwards S-shaped B365 is also elusive.


VDB 142

Jerry Lodriguss

To see these small objects, you'll have to magnify them. The tiny opaque spots named B163 and B162 — east and southeast of center — were invisible at 16x but readily noticeable at 64x. A large telescope and a filter will make seeing the dark spots against the bright nebula easier.

To meet the IC 1396 challenge, you have to use all the tricks of the trade. They include averted vision (looking off the edge of the eyepiece field), nudging the scope to stimulate your motion-sensitive eyes, and using a dark cloth over your head and eyepiece so no stray light interferes. Let us know how you fare.

the constellation Gemini, rise with Orion an hour later. Midway between these seasonal bright stars of summer and winter, Jupiter and Saturn add drama to the late fall sky. North of brilliant Jupiter lies the Great Square of Pegasus, and to its east is Pisces, home of Saturn.

The wonderful prototype variable star, Mira or Omicron (o) Ceti, lies southeast of Saturn in Cetus the Whale. Mira varies from magnitude 9.3 up to 3.4. Its period is 332 days, but its rise from dimmest to brightest takes only 126 days. Mira is predicted to reach peak brightness on December 11, so it will remain a naked eye star for the rest of the year. Mira is the best known of the long-period variable stars and its distinctive reddish color makes it easy to find.

Mars speeds across Leo and into Virgo during the month. Early risers can note its rapid easterly motion relative to the stars. This motion does not improve its rising time very much. Mars begins the month rising around 2 a.m. By the end of the month, the planet rises only 30 minutes earlier, though it does brighten from magnitude 1.6 to 1.4. Unfortunately, the planet is still quite far away and its tiny disk only reaches 5" across.

This is too small to see any appreciable detail on the surface with any telescope. Fortunately, the next few months will see a dramatic improvement as Mars approaches its April 24, 1999, opposition. The planet passes just 1° north of magnitude 4 Beta (β) Virginis on November 21 and is occulted by the moon in daylight on November 13.

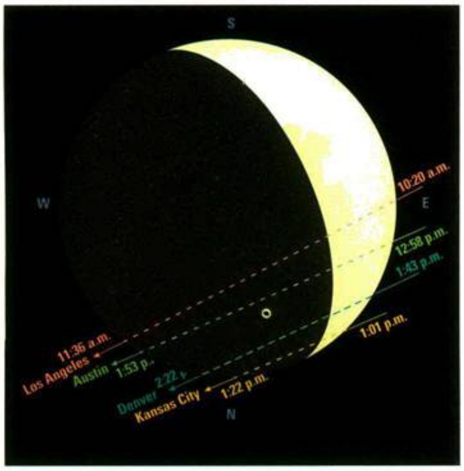
Speaking of occultations, East Coast observers can glimpse the occultation of Aldebaran on November 5 just after 7 p.m. EST (check the International Occultation Timing Association [IOTA] website at http://www.sky.net/~robinson/aldeb98.htm for specific times of disappearance and reappearance in your city). Almost three hours later, observers in the southeastern states might try for the occultation of Ceres. The asteroid is approaching opposition on November 28 and shines at magnitude 7.5. The asteroid will be a challenge to see with the 17-day-old moon shining brightly. Keep track of it mid-month as it passes north of Aldebaran on November 15 and close to the Hyades and Delta (δ) Tauri on November 27.

The month closes with the sun completing its seven-day journey through Scorpius and into what can be considered the 13th zodiacal constellation. On November 30, the sun passes into Ophiuchus. It remains there until December 18, when it passes into Sagittarius. **A**

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

The Moon Masks Mars

We have a relatively rare opportunity to witness the moon covering Mars on Friday, November 13. The event occurs during the day. Those who live east of Kansas City will only see the disappearance of Mars because the moon sets before Mars reemerges on the other side.

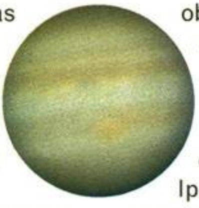


You will need a telescope to see the planet which glows at magnitude 1.5, against the hazy, blue western horizon. The waning crescent moon should be easy to spot — still six days before new. Mars will be to the left (east) of the moon. Once you've found it, increase the magnification to as much as the midday air will allow.

Because it takes the moon about 10 seconds to cover Mars, you may be able to share the eyepiece with others who would like to witness the event. Each observer will be able to see 5 seconds or half of the event.

The diagram indicates the times of disappearance and reappearance (if any) for your time zone.

Belts, Festoons, and Ovals



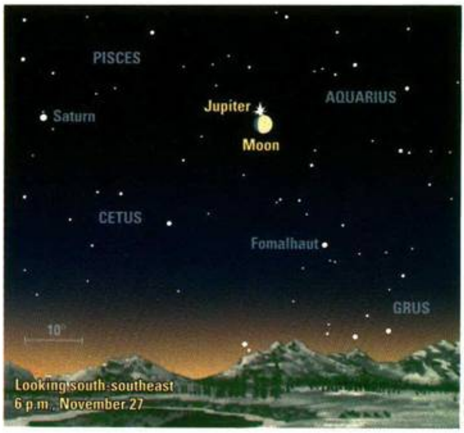
Now that Jupiter is finally up as twilight dims, it's time to get a good look at this fascinating planet. There have been some changes to the family of white ovals, so focus in on the cloud tops — there is a lot to see.

Novice Jupiter watchers will first see the two main cloud belts. With some study, and a scope larger than 4 inches, you'll find that the belts appear to be uneven. These regions are frequently disturbed by small white ovals that often work in pairs or triplets.

The Great Red Spot is the biggest treasure for the beginner. Though usually a prominent feature, last year this storm was dubbed the Pale Red Spot. Thanks to Jupiter's 10-hour rotation, the spot is often on the other side of the planet's disk and out of view to our telescopes. To increase your chances of seeing the Great Red Spot, use a blue filter to magnify the contrast.

Festoons are another often observed feature of Jupiter. They are thin wisps of darker cloud material that stretch away from a belt into a whiter zone. Unfortunately, festoons are only visible to observers with large telescopes or astro-imaging equipment.

To learn more about observing Jupiter, visit the Association of Lunar and Planetary Observers (ALPO) website at http://www.lpl.arizona.edu/~rhill/ alpo. There you will not only find information on observing Jupiter, but the other planets as well. Each individual planet's observing section offers information and advice to guide those interested in discovering the solar system through a telescope.



Looking south-southeast
6 p.m., November 27

ABOVE: Photo by Phil Barker

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Leo's Incandescent Rain

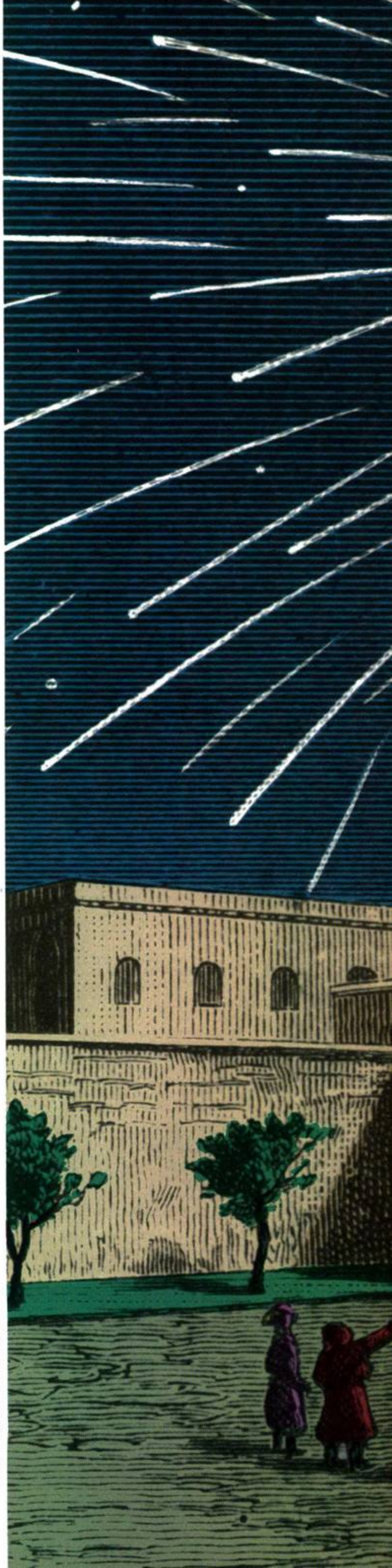
A celestial fountain in Leo may once again spout as Earth approaches the particle stream left in Comet Tempel-Tuttle's wake.

by Andrea Gianopoulos

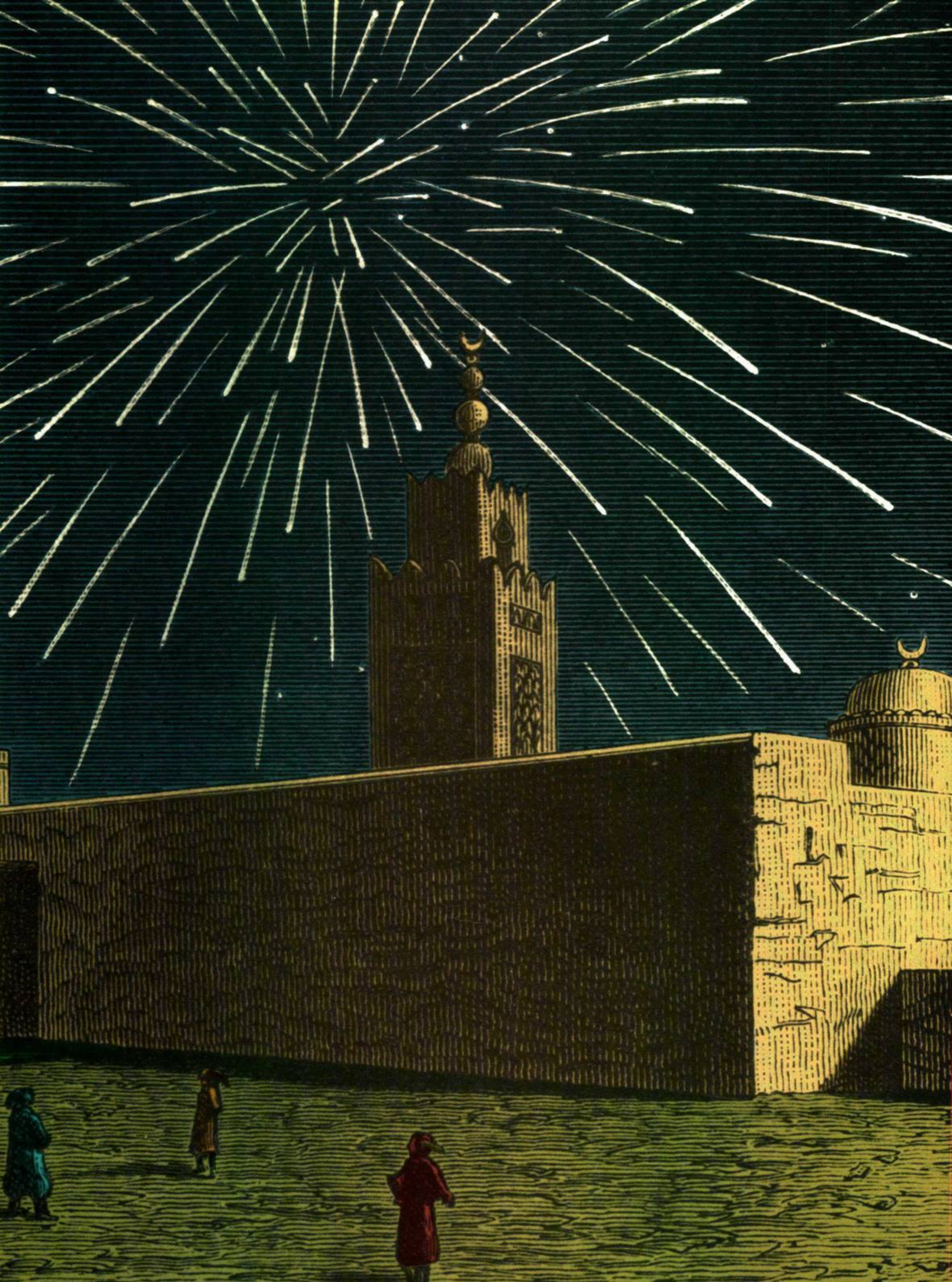
The early morning hours of November 13, 1833, brought up to 150,000 "flaming stars" per hour to the eastern half of the United States. Flashes as bright as "a streaking full moon" stirred many from their beds. Awestruck and frightened citizens gathered in the streets to watch the show. The absence of electric lights and the moon (a waxing crescent only two days old) made the display even more spectacular.

Meteors and meteor showers have long played an important role in cultural history: The 1833 event is credited, in part, with instigating religious revivals of the time. Written accounts of showers date back to at least 30 B.C. when the Roman poet Virgil wrote of the "long whitening seas of flame" left by stars that shot "headlong from the sky." Like the appearance of a comet or planetary conjunction, meteors were also thought to be symbolic of an earthly event — be it a kingly death, an earthquake, or the rise or fall of a city.

November 1998 could hold yet another Leonid storm, and the prospect has astronomers around the world preparing their observations. In Japan, the Okinawa airport will be the site of the Leonid Airborne Mission and mobile ground-based radar. Amateur and



Drawings colorized by *Astronomy*: Terri Field



The 1966 Leonids brewed quite a tempest in the skies over Arizona, New Mexico, and Texas. The early morning hours of November 17 brought a storm of 100,000 meteors per hour. While the deluge was also seen at a Russian polar arctic station, most countries reported rates less than 200 meteors per hour. Arthur Scott Murrell

professional astronomers will work together as they focus their efforts on the same parcel of sky, studying the Leonids from both the air and the ground.

Closer to home, Walter Marker of the Johnson Space Center (JSC) will study the ionization trails left by Leonid meteors as they enter Earth's atmosphere. Looking somewhat like a gigantic TV antenna, JSC's portable 50 MHz ionization radar was designed to study meteors, re-entering orbital debris, and the breakup of re-entering rocket stages. The facility's long wavelength is very sensitive to ionization trails left by incoming meteors. It can detect particles as small as 100 microns entering Earth's atmosphere. Such meteor observations help assess the hazards to spacecraft in Earth orbit.

Though understood today, meteor showers were once thought to be atmospheric phenomena. It wasn't until the Leonids put on their spectacular display over North America in 1833 that astronomers began to question and subsequently understand their origins. The 1833 display spurred research into the nature of these "falling stars."

Denison Olmsted, Professor of Mathematics and Natural Philosophy at Yale University, is credited with the birth of meteor science. After the 1833 storm, Olmsted gathered every description and account he could find of the event. He pored over the material, publishing his results in the *American Journal of Science and Arts* in 1834. Olmsted concluded that the meteors were particles which entered the atmosphere at high velocities. He established their radiant in the constellation Leo, and from that time forward "November's meteoric phenomenon" was referred to as the "Leonid meteors."

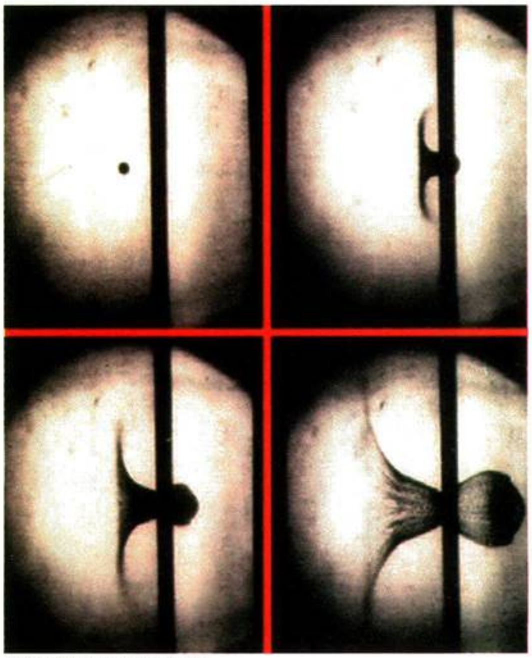
To get a better understanding of what it was like to witness that spectacular 1833 event, take an evening drive

Satellite Sandblast

Fewer than 100 satellites were in orbit during the last major Leonid storm in 1966. Today, more than 500 weather, defense, communication, navigation, and environmental monitoring satellites perform critical tasks high above Earth's surface. What effects will the Leonids have on these high performance electronic instruments?

The problem is the speed of these particles, not their size. The cometary debris that gives rise to annual meteor showers like the Leonids is typically smaller than the diameter of a human hair and no larger than a grain of sand, but "the encounter velocity is enormous," said William Ailor, director of the Center for Orbital and Reentry Debris Studies at The Aerospace Corporation in El Segundo, California. Leonid particles encounter spacecraft at about 71 kilometers per second (more than 155,000 miles per hour) or 200 times the speed of sound. "The result is that even a grain of sand the size of the head of a pin has the same energy as a .22 caliber bullet," Ailor continued. He was speaking before the Subcommittee on Space and Aeronautics, a panel of the House Committee on Science.

Though some satellites may be critically damaged by an impact with one of these speeding bullets, most will experience no more than a pitting of their optical surfaces and mirrors. During the short Leonid bombardment, it is estimated that satellites will experience one to three years of weathering that will degrade their performance.



NASA/JSC Hypervelocity facility

The biggest threat comes from the formation of an electrically charged cloud called a plasma, or from free electrons on the spacecraft. At these velocities, the impact of the smallest particles can create a plasma. The sudden electrical pulse created by the impact can damage sensitive circuits and computers on the satellite in the same way a lightning strike can create a power surge that damages your home computer and audio-visual equipment.

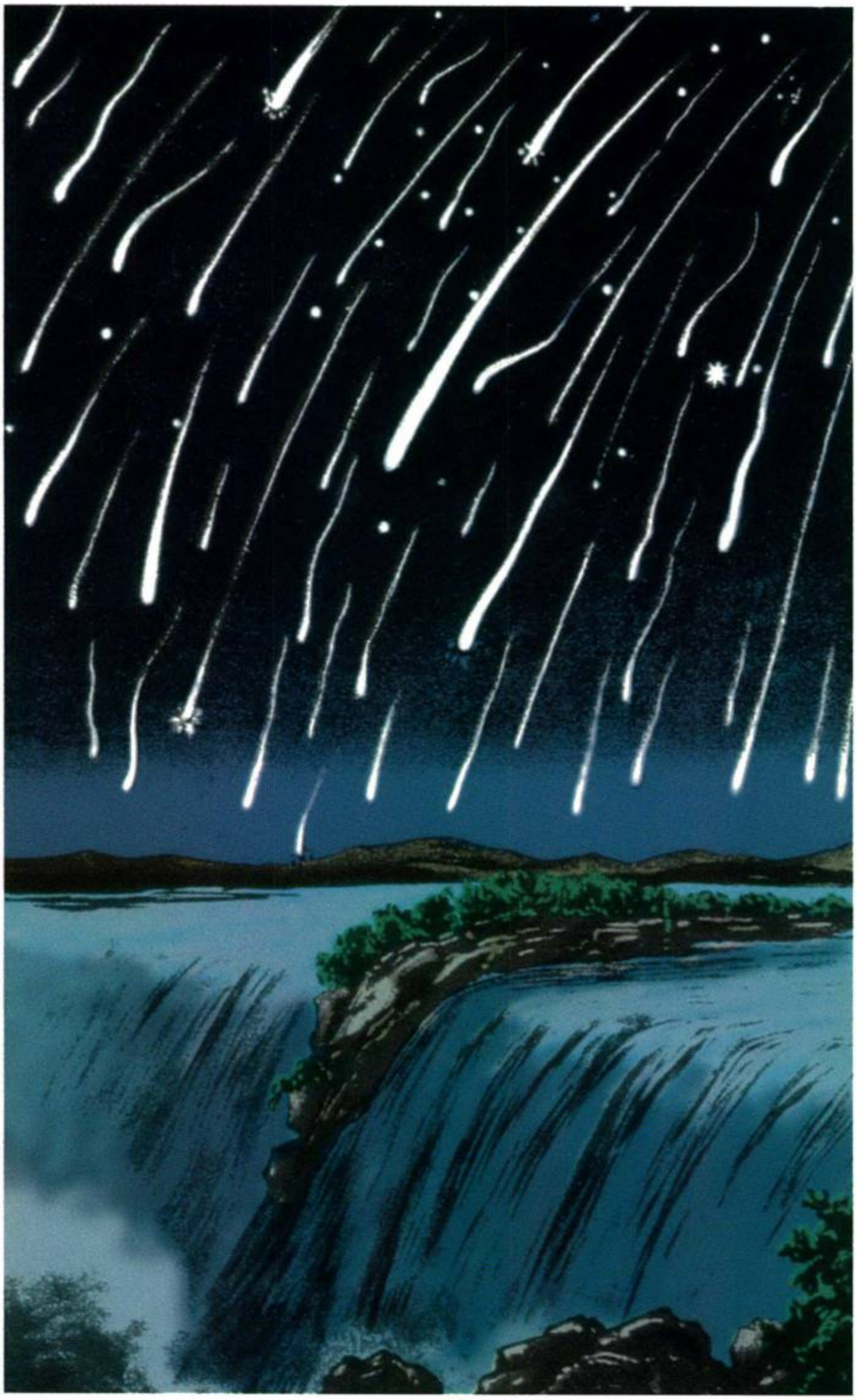
Though most military satellites are combat ready — they are designed to withstand a nuclear assault — communications and weather satellites are another matter. Two of the precautions being taken to safeguard these satellites include a powering down of sensitive equipment and repositioning. The idea is to turn power off and point the most sensitive areas away from the shower's radiant. During the 1993–94 Perseids, the Hubble Space Telescope had its backside facing the radiant, while observations continued in the direction opposite the radiant.

In 1993, the European Space Agency's Olympus telecommunications satellite was lost during the Perseid meteor shower. There is also anecdotal evidence that cosmonauts heard the sound of particles colliding with Mir during that same shower — some of these impacts were said to have damaged the facility. In 1998, the Leonids have the potential to do even greater damage. This year's event will help scientists better prepare for the future.

through a snowstorm. As the car cuts its way through the falling snow, white flakes appear to come directly at you — spouting from one central point just beyond the headlights. Common sense says the snow should be falling vertically, not horizontally. But your perspective is changed by the car's motion. Meteor storms (and showers) are similar in that the "falling" or "shooting" stars appear to diverge from a point in the sky called the radiant. As with the moving car, this optical illusion is caused by Earth's motion through the solar system. The very nature of meteor showers also contributes to the effect.

Annual meteor showers like the Leonids have their origins in comets. As these big dirty snowballs travel toward the inner part of the solar system, their ice begins to sublimate (transform directly from a solid to a gas) in the warmth of the sun. This process releases dirt and dust that lingers in the comet's wake. Like a cosmic dust bunny, the particles are left to circle the sun in the comet's orbit. If Earth passes near that orbit, the planet's gravity sweeps up the particles and they fall through the atmosphere, vaporizing as they go.

The Leonids' parent comet is 55P/Tempel-Tuttle (55 is the comet's number while the P indicates the comet is periodic). It was discovered in Ursa Major on December 19, 1865, by Ernst Wilhelm Liebrecht Tempel. A few weeks later, on January 6, Horace Parnell Tuttle independently spotted the



comet. Though only visible for one month after Tuttle's discovery, astronomers were able to calculate its 33-year orbit. Tempel-Tuttle's most recent journey by the sun (perihelion) was on February 28, 1998. A few days later, on March 5, it crossed the plane of Earth's orbit. Does this recent encounter mean we'll have another storm like the one seen in 1833 or more recently in 1966?

The rates associated with Leonid storms after 1833 have been sporadic. An estimated 100,000 shooting stars per hour graced the skies of the southwestern United States during the 1966 storm. One person who might know what 1998 will bring is Donald K. Yeomans with the Solar System Dynamics Group at the Jet Propulsion Laboratory in Pasadena, California. His research, with colleagues Kevin Yau and Paul Weissman, indicates that the 1998–99 Leonid meteor shower could be similar to the showers seen in 1866–67 and 1931–32. These showers had zenithal hourly rates (the number of meteors seen per hour when the radiant is directly overhead, at the zenith, under ideal sky conditions) of 5,000 and 200, respectively. Though quite a broad range, the average Leonid shower produces only 10 to 15 meteors per hour — a meteor shower reaches storm levels at one meteor per second or 3,600 meteors per hour.

Observers in the United States probably won't have as good a view of the Leonids as they did in 1833: Earth passes through the main particle stream during daylight hours (around 3 p.m. EST, noon PST) on November 17. Those living in North America may see increased activity just before dawn, but the best spot to view 1998's shower is in Japan or eastern Asia.

Hopes are also high for 1999, but here too the United States is not the best place to be. For this appearance of the Leonids, meteor watchers should head to Europe or North Africa.

Even if you aren't in the best spot to see a possible Leonid storm, the increase in activity makes it worthwhile to observe. You don't need any special equipment to see the Leonids. The only requirements are warm clothes and dark skies. Remember not to stare directly at the radiant, located in the sickle or backward question mark of Leo. Here the meteors will leave very short streaks. The best spot to watch is roughly 45° from the radiant and the horizon — simply lying back in a sleeping bag and looking up works well too.

If you spot a meteor, trace its path back across the sky to see if it intersects the radiant. By doing this, you can distinguish sporadic meteors from those that are part of the shower. The truly ambitious observer will note the time of appearance, color, and magnitude — you can compare the meteor's magnitude to the stars in the area. You may also want to chart the activity by watching the shower for a week before and after the November 17 peak. Another good tip is to observe with a friend or two. It's always more enjoyable to share such an experience, and your ooohs, aaahs, and wows will help feed everybody else's enthusiasm. Remember to give yourself a break every now and then. Early mornings in November can be bitterly cold, so take time to drink a hot cup of coffee, tea, or hot chocolate. Above all else, have fun. You may not see the fireworks of 1833 and 1966, but you will definitely enjoy the show. ■

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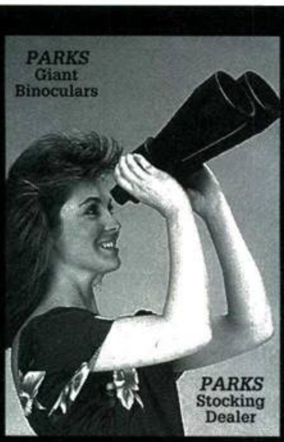

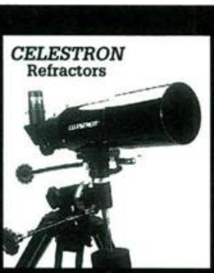

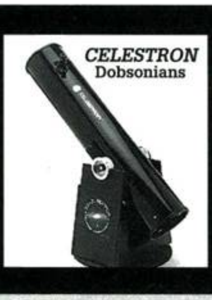

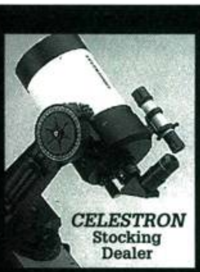

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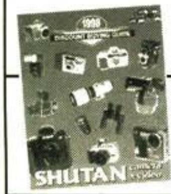

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Space in the

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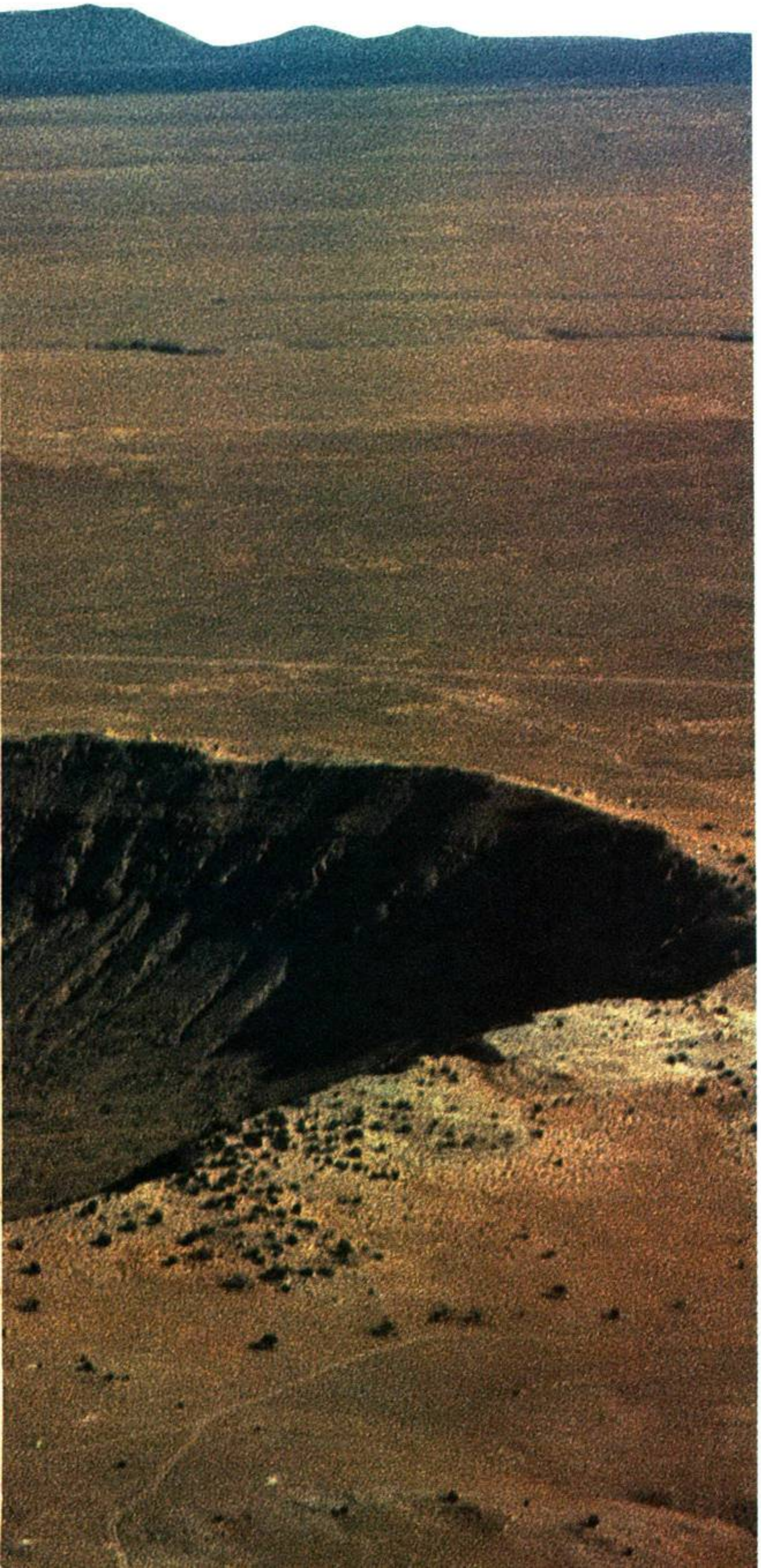
Arizona's Meteor Crater and Lowell Observatory bring visitors visions of earthly impacts and distant planets.

by Nancy L. Hendrickson



Meteor Crater Enterprises, Inc.

The face of Arizona bears the wear and tear of its geologic past. In the center of the state sprawls the Valley of the Sun and Phoenix. They lie at the tip of the Sonoran Desert, a prehistoric seabed that stretches deep into northwestern Mexico. Jagged mountains such as the Camelback, Papago Peaks, and South Mountain Peak rim the city. North of it, the edge of a wide shelf of land called the Mogollon Rim plunges 2,000 feet into the Tonto Basin. It separates the great expanse of the Sonoran Desert in the south from the Painted Desert and Colorado Plateau to the northeast. Forests that once witnessed the great dinosaurs are now petrified in the parched sand, as silent as the long-dead beasts that wandered among them millions of years ago. And even farther north, the Colorado River carves a canyon that can only be named "Grand." But in a state whose geology runs to the extreme, Meteor Crater goes off the scale.

About 50,000 years ago, long before big-game hunters stalked mammoth and bison across grasslands, an iron-nickel meteorite slammed headfirst into Arizona. A blast equal to 20 million tons of TNT blew out a crater nearly a mile wide and 600 feet deep. It would puzzle geologists well into the 20th century.

Geoff Chester

Stars trail behind Lowell Observatory in Flagstaff. It was here that Clyde Tombaugh first identified Pluto.

To visit this place is to visit the moon. In fact, Apollo astronauts trained here in the 1960s to prepare for their trip to the moon. To visit this place is to visit Mars. The red Sedona landscape mirrors the martian world, at least in color, as much as any place on Earth. To visit this place is also to glimpse a bit of history. Meteor Crater was the first meteorite crater identified on Earth, and studying it has given scientists great insight into the effects of impacts.

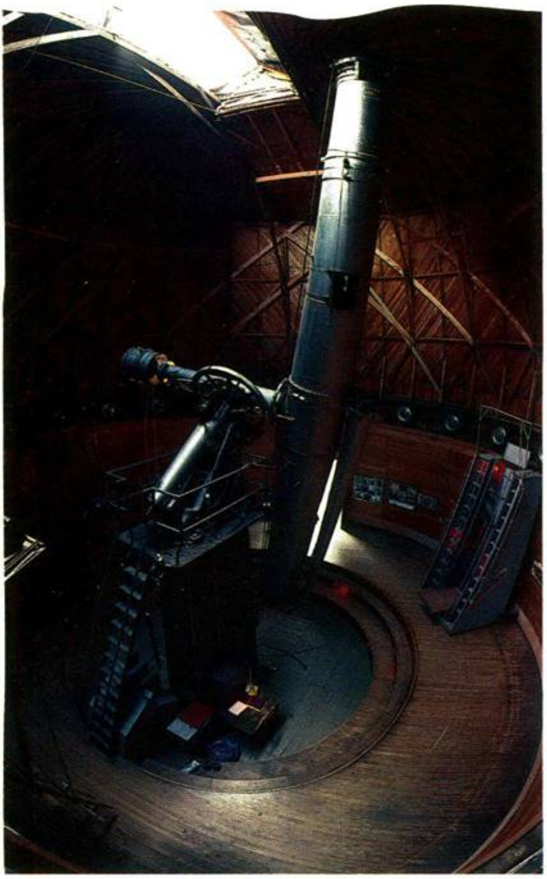
I came to Meteor Crater for the first time in 1995 with my friend, David Cortner. We approached it from Flagstaff, an old railroad town standing at the base of the San Francisco Peaks and smack in the middle of Arizona's prehistory. Just north is Sunset Crater, a volcano whose last eruption was just a few moments ago, in geologic time. The Sinagua ruins of Wupatki are close by, evidence that architecture and landscape can live together in peaceful harmony. Just east, on the way to the crater, we passed the exit for Walnut Canyon, one of the best preserved, and least visited, of the Sinagua ruins.

I don't know what it was like the day the crater was born, but on this day the Arizona sun burned hot. Not as unbearable as south of the Mogollon escarpment, thanks to a constant breeze, but hot just the same. The sensible critters had gone underground except us. Here and there a desert wildflower peeked up from the red stone slabs: bright yellow prickly pear, purple thistle, orange and red Indian blanket.

For the most part, the land here is flat, broken only by arroyos, splaying out like so many crooked fingers. Far to the north, haunting Hopi mesas became lost on the horizon; behind us rose the mountains around Flagstaff, ahead of us stretched the flat expanse that paralleled the American classic, Route 66. About ten miles from our destination, David pointed off to the right. "That," he said gesturing at a distant rise, "is the crater's rim."

That simple statement left me dumbfounded. Across the monotonous land, a long mound appeared. As we turned down the road to the visitor's center, the ridge grew higher and higher. I had always pictured standing on the crater's precipice, looking into its depths, but I had never imagined that I would have to climb up to look down. The force of the blast had pushed the surrounding limestone up 150 feet to form a monstrous rim. As we got closer, I felt more and more like we were two kids on an extraterrestrial adventure. For one long breath I was on the moon and my astronaut-amigo had just said, "See that rise over there? That's Copernicus." Okay, so Copernicus dwarfs Meteor Crater. But proximity colors the logic of comparison. If this was even a tiny fraction of what the moon walkers felt, I can die happy. I've walked on the moon.

After paying our entrance fee, we climbed up what seemed like countless steps, finally reaching the rim. I know some brilliant scientific thought should have come to mind, but my first words were: "Wow. This is a really big hole."


Astronomy: David J. Eicher

Percival Lowell used the 24-inch Alvan Clark refractor to complete his celebrated studies of Mars.

Knowing that the crater is nearly 600 feet deep and actually seeing the view from its edge is like comparing physics with the thrill of bungee cord jumping. They share a common thread but stir different parts of the body. One guidebook to Arizona claims that 20 football games could be played simultaneously on the crater's floor, with room on the slopes for two million fans. Can you imagine having the concession franchise at this stadium? If Meteor Crater is this impressive, what must it be like to stand on the edge of my old friend Copernicus?

Native Americans spied this hole hundreds of years before we did. Their artifacts have been discovered along the rim. Europeans didn't pay much attention to it until 1891, when a wandering prospector noticed large amounts of iron scattered about the edge of the impact site. Many geologists who inspected the area attributed the crater to a volcanic steam explosion. In 1903, lawyer and geologist David Moreau Barringer filed claim to the land, after hearing rumors of meteorites. He had hopes of mining the rocks for their high concentrations of iron and nickel. Eventually his field work led to a paper claiming the cosmic origin of the impact crater. But he could never find the meteorite in question. Surveys and studies conducted later still could not conclusively solve the crater's origin.

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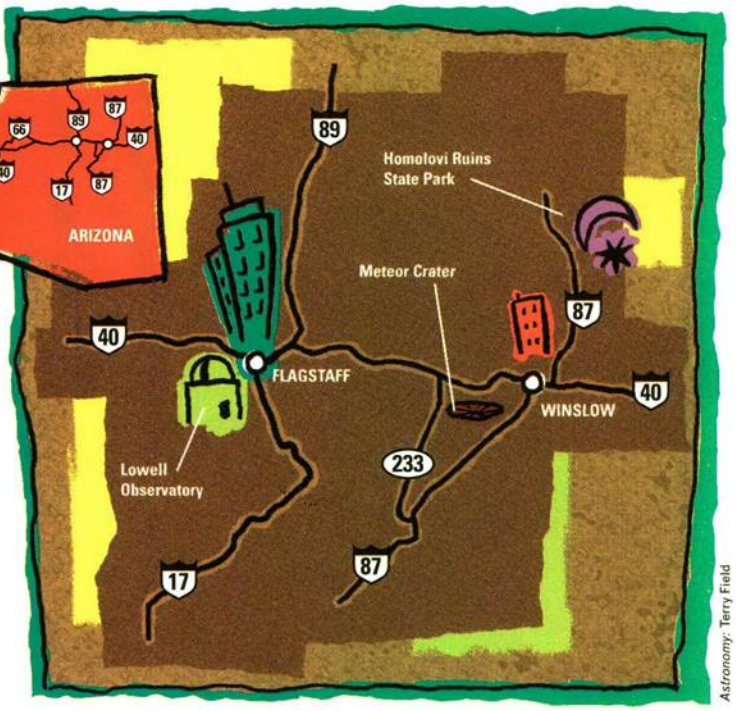
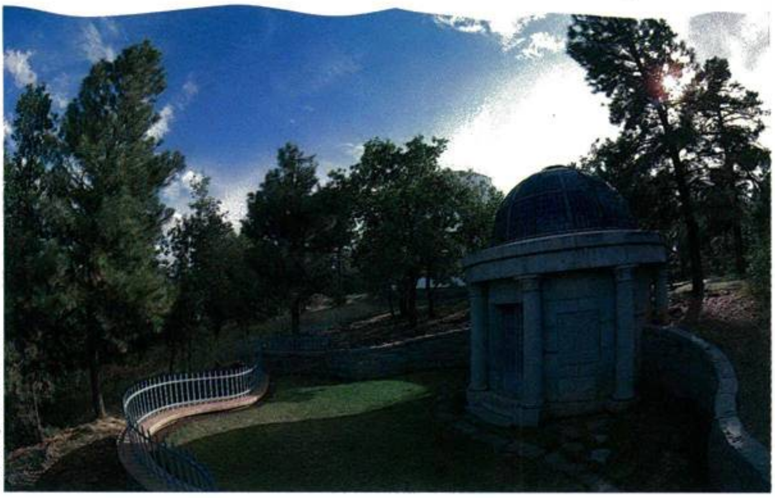
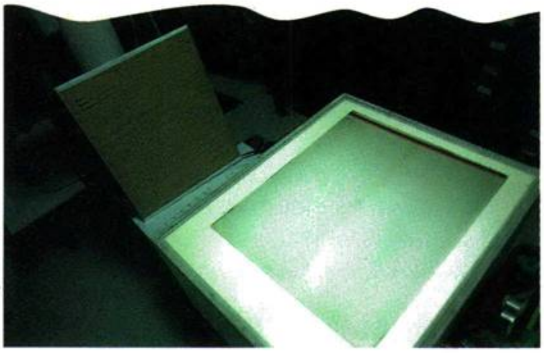


Astronomy: Terry Field



Astronomy: David J. Eicher

Lowell's tomb (above) serves as a permanent shrine to observing.



Astronomy: David J. Eicher

One of the famous photographic plates (right) on which Clyde Tombaugh discovered Pluto.

Then, in 1957, geology student Eugene Shoemaker began investigating the crater. In one of Barringer's old drill shafts, Shoemaker found a level of broken rock. Below this he found shock-melted glass embedded with meteoritic bits. His work convinced geologists that a huge impact shattered and fused the rocks. By studying Meteor Crater, Shoemaker essentially founded the science of impact geology. His work prompted scientists to reinterpret the surface of the moon. Previously they thought that the craters on the moon were remnants of old volcanoes. But Shoemaker's work showed that impacts caused the craters.

David and I spent time, too, in the Astronaut Hall of Fame, taking a brief trip into the glory days when we strove to gain the moon. Did those Apollo astronauts ever really look that young?

After a few more pictures and a glance back at the rim, we retraced our route to Flagstaff, stopping at Lowell Observatory up on Mars Hill.

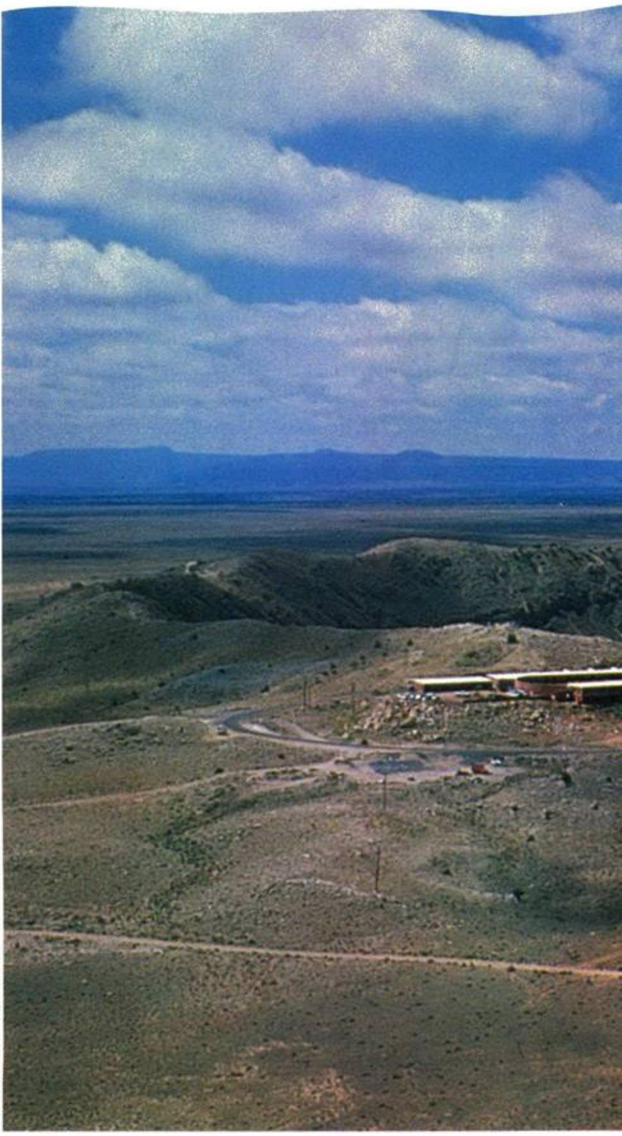
We arrived just in time for one of the daily tours. Following a guide over the grounds perched high on a mesa, we took in the view of pines and wildflowers below a blue canopy of Arizona sky.

The modest Ponderosa Pine observatory was built in 1894 by Bostonian Percival Lowell. It was Arizona's first, and the 24-inch Alvan Clark refractor telescope is the observatory's centerpiece. The 32-foot-long scope was purchased for $20,000 and transported by train from Boston in 1896. Lowell used the Clark to complete his famous studies of Mars, by which he claimed to have observed canals on the Red Planet. Replete with a kitchen pot doing double duty as a scope cover and a dome that rotates on truck tires, the scope moves as smoothly on its mount as a sleek schooner slicing through calm seas.

In the 1960s, Shoemaker and his colleagues used the Clark in conjunction with the 36-inch refractor at Lick Observatory for a moon mapping project. Still in use today, the big refractor has been registered as a national historic landmark.

Down the hill and up another is the Pluto Dome, home of the Pluto Camera, the 13-inch refractor Clyde Tombaugh used to discover our ninth planet. Between 1929 and 1930, he and others photographed the sky on glass plates. Tombaugh then used a blink comparator, a device that compares two plates and highlights moving objects. One moving speck turned out to be Pluto.

Prints of the Pluto discovery photos are on exhibit in the Rotunda Library. So, too, is a blink comparator. You can actually look through it to see how a moving object seems to jump out of the



Meteor Crater Enterprises, Inc.

picture. My favorite display, though, was a collection of Lowell's original sketches of Mars. David and I both wanted to get our hands on them for a closer look, but the glass case kept us at bay. We were going to stay for the public viewing through the Clark, but Arizona's usually clear skies turned stormy, sending us back down Oak Creek.

The next day we were out early, traveling to an ancient Anasazi petroglyph site. The prehistoric people who once lived here left behind a rock tablet library that details their existence. Scrambling over truck-size boulders, we encountered one of the biggest glyph galleries I'd ever seen. We also stumbled onto an area strewn with pottery shards and chipped stone tools. Although I left behind all the artifacts, I did pick up an empty rifle casing (post-Anasazi, I believe), which today serves as the North Star finder on my barn door mount. I call it the Anasazi Sure Shooter.

Although David and I hoped to find a petroglyph like the one at Chaco Canyon depicting the Crab Nebula supernova of 1054, no such luck. Shamans and deer, but no exploding stars.

In cosmic terms, the glyph gallery was within spitting distance of the crater. What would it have been like to have been standing here on that day 50,000 years ago when the sky fell in? Surely, we would have met our end. That made us wonder what it must have been like the day, millions of years ago, a giant meteorite supposedly slammed into Earth and wiped out the dinosaurs. Did they catch the blazing rock out of the corner of their eye as it hurtled to ground zero? What was it like to witness the explosive event? How did it sound? We let our imaginations run wild as we conjured up the "what-ifs." Some of our answers were silly, some studied. The best we could do, of course, was speculate. But sometimes, isn't that the most fun?

Nancy L. Hendrickson returns to Meteor Crater almost every year, and still she says, "Wow! this is a really big hole!" When not at the crater, you can find her scheming Great Western Trips with David Cortner. You can reach her at stjoemo@ibm.net

The visitor's center abuts the rim of Meteor Crater in Northern Arizona, which rises 150 feet above the flat expanse of desert.

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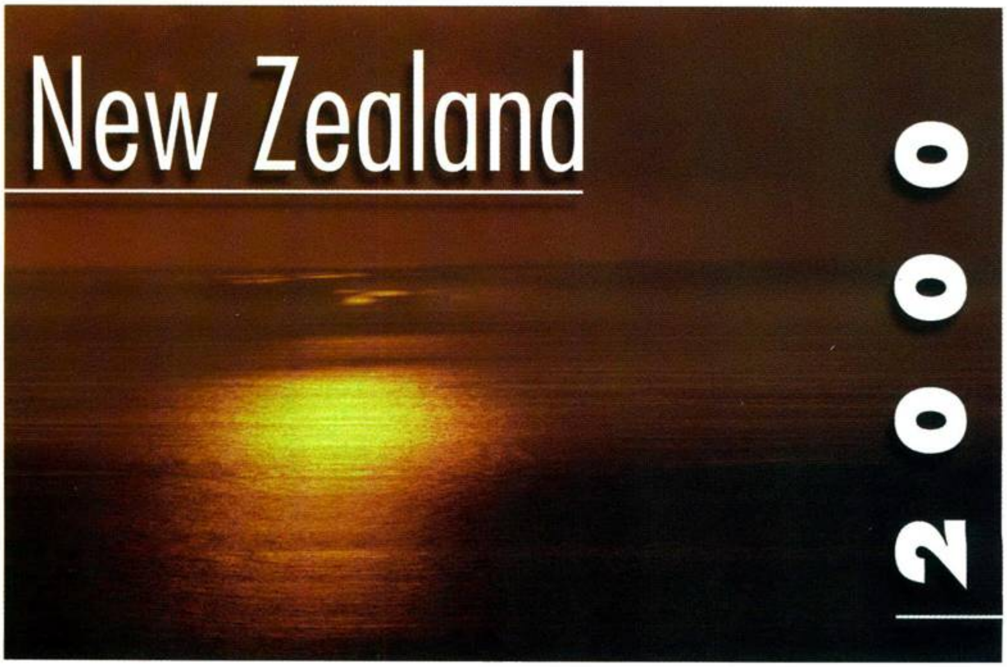

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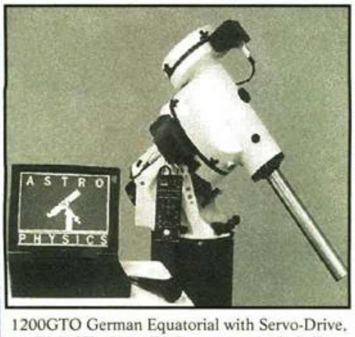

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ask Astro

Globular Planet, Oort Cloud, Choosing a Dark Site.

Q: If I lived on a planet orbiting a star near the center of a large, dense globular cluster such as M13, what would the night sky look like? — *Jim Crannell, Nashport, Ohio, and Rick Dorrego, Miami, Florida*

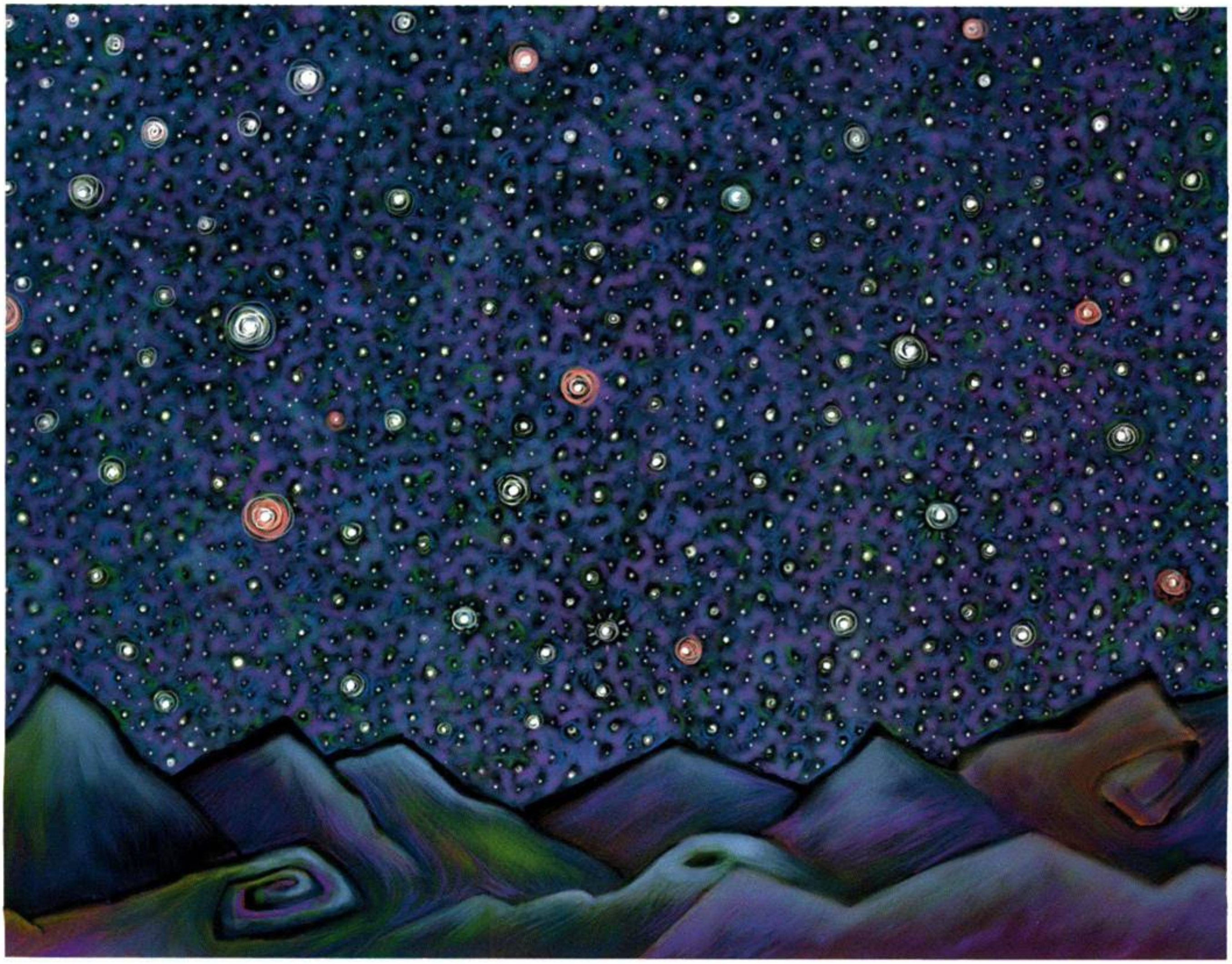
A: Globular clusters are roughly spherical collections of hundreds of thousands of stars that are crammed into a volume of space typically 100 to 150 light-years across. About 150 globular clusters are known to orbit the Milky Way. Globular clusters are very old; some of them were among the first objects to form in the universe. Because massive stars use up their fuel quickly, in an old object like a globular cluster, only relatively low-mass stars are left. All the other stars have either blown up or faded away.

Most globulars have very tightly packed cores, with the majority of the stars lying within a few tens of light-years from the center. As you might expect, the night sky would be ablaze with stars, although the night sky of most globular cluster planets would still be dark.

Most of the stars would be faint, low-mass stars redder and dimmer than the sun. There might be hundreds of thousands of them in the cluster, but only a few tens of thousands might be visible because they are so intrinsically dim. They might contribute to a hazy background in the sky, like our own Milky Way.

But that would hardly be noticed compared to the intense brilliance of the evolved stars, the giants that have started fusing helium in their cores. These stars come in many flavors, including very red to dazzling blue. You would see hundreds, and some may appear as bright as magnitude –7

The night sky in a globular cluster would have hundreds of stars brighter than any in Earth's night sky. *Astronomy*: Terri Field



or so, making them at least 10 times brighter than Venus at its brightest (which is magnitude –4.5). The sky would be a sparkling fireworks display of dozens of stars brighter than any star or planet visible from Earth's night sky, and hundreds that would even rival Sirius or Canopus. It would be quite a sight to behold. — *Phil Plait, Advanced Computer Concepts (My thanks to Wayne Landsman for some helpful advice.)*

Desert regions are prime sites for viewing the night sky. Jackie A. Giuliano

Q: Has anyone ever seen the Oort Cloud or does anyone have proof of its existence? ***— Erik DeWitt, East Haven, Connecticut; Robert E. Meyer, Cuenca, Ecuador; and Kevin Overton, Greeley, Colorado***

A: In a nutshell, no and no. Dutch astronomer Jan Oort noticed in 1950 that the long-period comets (those with orbital periods greater than 200 years) appear to fall into the solar system from huge distances and random directions. He postulated the existence of a cloud of comets surrounding the sun, from which the short-lived comets of the inner solar system might be resupplied. This cloud would have formed 4.5 billion years ago when proto-Uranus and proto-Neptune ejected debris from their surroundings in a kind of gravitational slingshot. Debris farther from the planets escaped ejection and later formed the Kuiper Belt, now recognized as an independent source of short-period comets.

About a trillion comets are needed if gravitational deflections by passing stars are to be responsible for sending in the observed comets. Unfortunately, comets in the Oort Cloud are so far away (the radius is roughly 50,000 AU) that there is no hope of a direct detection. For example, the nucleus of Comet Halley at 50,000 AU would appear at magnitude 60. That's a trillion times fainter than the faintest objects in the Hubble Deep Field and far beyond the reach of any foreseeable telescope or detector.

For this reason, there are no direct observations of the Oort Cloud and none are expected until we send a spacecraft there. On the other hand, we have no better idea for the origin of the long-period comets, and Oort's hypothesis does explain the distribution of the sizes of the orbits of comets remarkably well.

So, we don't have absolute proof, but it seems a good bet that Oort was right and that his cloud is real. *— David Jewitt, University of Hawaii*

Q: Where should one travel to find the best dark site to observe from, based on weather, location, terrain, etc., that could be reached without travel difficulties? ***— J. Scott Langworthy, Lake George, New York***

A: If you're looking for an ideal place to observe, and if you can afford modest travel expenses, it's hard to beat the desert. Some arid regions average well over 330 clear nights a year. Aside from that, deserts are free of haze-producing moisture. They also tend to be thermally homogeneous, which means there are few temperature differences to create winds and unsteady seeing. And because most arid regions are sparsely populated, light pollution is rarely a problem. With this in mind, many amateur astronomers find celestial nirvana in America's desert Southwest. Others soak up magnificent views in the deserts of South America. And for the ultimate winter vacation, some Northern Hemisphere observers trek to Australia's desert outback, where an utterly alien southern sky adds to the dark-sky spectacle. *— John Shibley*

Q: Why are there no green and violet stars? Stars produce visible light, and color is visible light, so why don't stars produce green and violet light? ***— Trent Revis, Vashon Island, Washington, and Craig Gallagher, Medford, Oregon***

A: Stars do indeed produce green light, but it is so mixed in with other colors that you do not sense it. Stars radiate all colors across the optical spectrum, from red to violet. The color you see depends on the intensity of the colors present in the starlight, on the sensitivity of your eye to each of the colors, and on the absorptive properties of Earth's atmosphere.

The intensity of each color in starlight depends on temperature. Cool stars radiate a lot of red light and very little blue, so, like Betelgeuse and Antares, they appear reddish to the eye. As temperature increases, stars radiate relatively more green and blue light. However, a star that radiates mostly green light will look white because of the mixture of the other colors; one that radiates mostly blue and violet light will appear only slightly bluish. — *James Kaler, University of Illinois*

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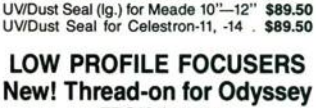

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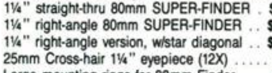

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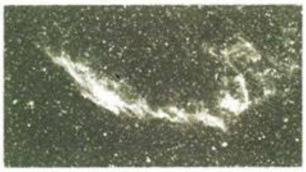

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†U.S. Patent 4,473,636

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STAR STUFF

A PRODUCTS

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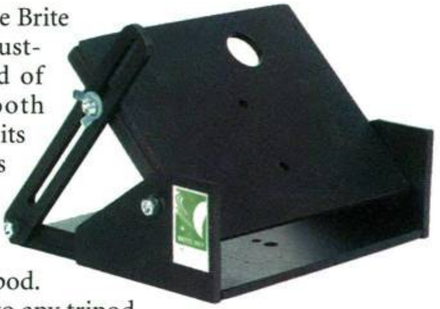
Opticon's Large Mirrors can be produced in flat, spherical, and aspherical shapes with surface roughness between 15 and 50 angstroms RMS, and all the mirrors are inherently thermally stable. The mirrors have been used in satellites, radio and astronomical telescopes, military and communication systems, and physics experiments. Opticon's Large Mirrors are custom engineered and priced according to materials, size, and quantity. Literature and price quotes are available upon request.

Opticon Corporation, 76 Treble Cove Road, North Billerica, MA 01862; phone, (978) 663-6105, ext. 12; fax, (978) 663-0015.

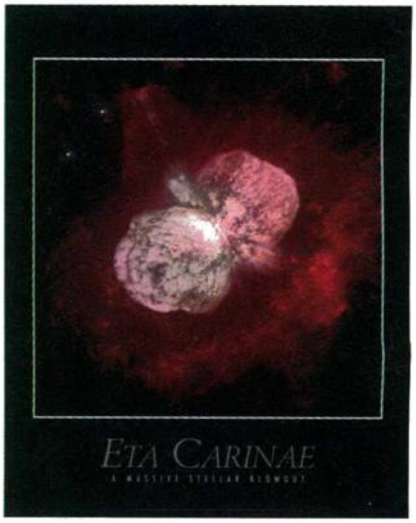
Brite Sky ETX Wedge

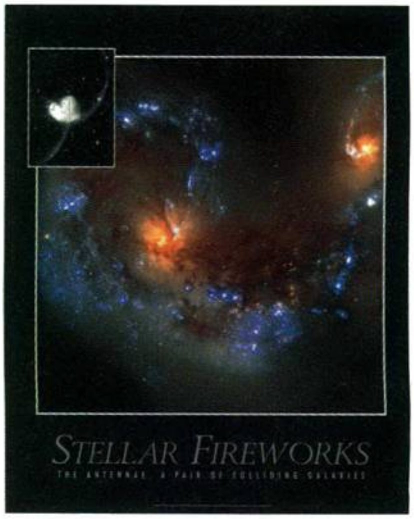


▶ Designed for Meade ETX telescopes, the Brite Sky ETX Wedge is a light and sturdy rust-resistant equatorial wedge constructed of anodized aluminum. It features smooth declination axis movement, which allows its users access to the full range of latitudes from the equator to the poles. The wedge will accept both 1/4-20 and 3/8-16 mounting posts, making it an easy fit for any sturdy photo or video tripod. Though the Brite Sky Wedge will mount to any tripod, the Bogen tripod leg set without a head is recommended for best performance.

Brite Sky Products, 5b First Street, Dover, NH 03820; phone, (603) 743-4083. Brite Sky ETX Wedge: $139.95.

Hansen Planetarium Publications Full-Color Posters

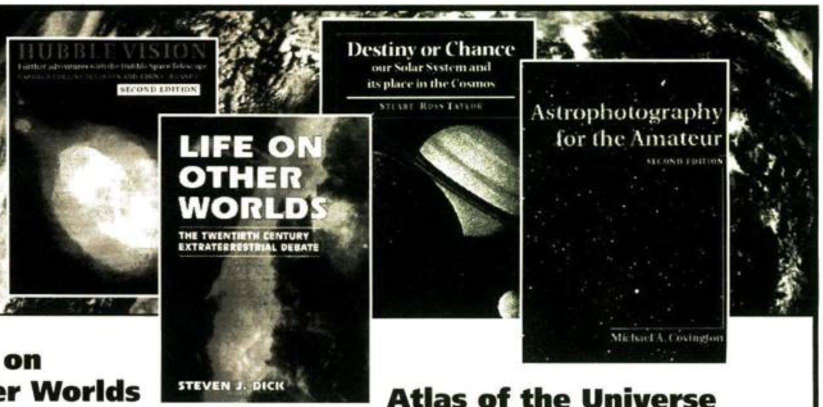




▶ For more than 20 years, Hansen Planetarium Publications has been publishing the finest images of Earth and the heavens. To continue this tradition, they are proud to introduce their three newest stunning images, all available as full-color posters. The posters, which are printed on quality recycled paper and available either on paper or laminated stock, feature spectacular images of star clusters, Eta Carinae, and a panoramic vista of Mars. Stellar Fireworks, which measures 24" by 30", is a spectacular deep-sky image taken by the Hubble Space Telescope revealing more than 1,000 bright young star clusters bursting to life at the heart of a pair of colliding galaxies. Eta Carinae, also taken by Hubble and measuring 24" by 30", shows two polar lobes of billowing gas and dust moving outward at a rate of 1.5 million miles per hour. Lastly, Mars: A Panoramic Vista, measuring 13" by 39", is a fantastic 360° panorama taken by Mars Pathfinder that captures the martian landscape as it has never been seen before. Each poster is accompanied by a detailed reference guide that clearly explains what's being pictured as well as how the image was created. Hansen Planetarium Publications also offers a full line of previously published posters, including images of Neptune, Uranus with five moons, the first launch of the Space Shuttle, Challenger above Earth, and many more.

Hansen Planetarium Publications, 1845 South 300 West, #A, Salt Lake City, UT 84115; phone, (801) 483-5400; toll-free order line, (800) 321-2369; fax, (801) 483-5484. Stellar Fireworks and Eta Carinae: $10 (paper), $20 (laminated); Mars: A Panoramic Vista: $7 (paper), $12 (laminated).

Reach for the Stars with Cambridge



Hubble Vision

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Carolyn Collins Petersen* and *John C. Brandt

This eagerly-awaited second edition is the most comprehensive, most authoritative and best illustrated popular book available on the Hubble Space Telescope. It provides a magnificent portfolio of the latest images from the HST, woven together with a lucid text explaining the most exciting discoveries and setting them in the context of our current understanding in astronomy. The second edition has been completely revised, updated and expanded to include all the latest astronomical discoveries—from supernovae and protostars to gravitational lensing, black holes and the early universe. More than 100 new illustrations make this a truly comprehensive look at the Universe.

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Based on suggestions from readers of the first edition, the new edition has been completely updated and expanded to include new chapters on computer image processing and CCD imaging; expanded advice on choosing cameras and telescopes; completely updated information about films; a much larger bibliography; and hundreds of new photographs demonstrating the latest equipment and techniques.

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The 20th-Century Extraterrestrial Life Debate

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Life on Other Worlds chronicles the history of the twentieth-century extraterrestrial debate. In a nontechnical manner, author Dick places it in historical perspective, showing how the concept of extraterrestrial intelligence is a world view of its own—a "biophysical cosmology" that seeks confirmation no less than physical views of the Universe. The debate rests at the very limits of science, and attempts at confirmation only illuminate the nature of science itself.

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Stuart Ross Taylor

Written by a leading planetary scientist, this book tells the remarkable story of how our solar system came into existence. It provides a fast-paced and lucid tour of our new understanding of the Earth, its planetary neighbors and other planetary systems.
In a whirlwind adventure, Dr. Taylor shows how the formation of mighty Jupiter dominated the solar system, why Mars is so small, where comets come from, how rings form around planets, why asteroids exist, and why Pluto isn't a planet at all.

1998 256 pp.
0-521-48178-3 Hardback $24.95

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▶ Now available from Adorama Inc. is a new series of giant binoculars that feature large apertures and bright viewing in a compact housing. Breathtaking wide-field views of astronomical objects as well as terrestrial views under low-light conditions will be yours with either the 70mm or 80mm Giant Series Binoculars. The 70mm Giant Series features fully multi-coated optics, high-quality BAK-4 prisms, center focus with right diopter adjustments, and a wide field of view. Both 11x70mm and 16x70mm binoculars weigh 2.8 lbs. The 80mm Giant Series binoculars are larger in size than the 70mm and provide 30 percent more light-gathering power. They also feature fully multi-coated lenses and BAK-4 prisms. Available in 11x80mm or 20x80mm, each pair weighs 5.24 lbs. The 11x80mm pair may be hand-held for general use but a tripod is recommended for extended use. The 20x80mm pair, perfect for more detailed close-ups, requires a tripod. All binoculars come complete with a durable hard carrying case, straps for the case and the binoculars, rubber eye-cups, and a built-in tripod adaptable socket.

Adorama Inc., 42 West 18th Street, New York, NY 10011; phone, (212) 741-0401; fax, (212) 727-9613. 11x70mm Giant: $199.95; 16x70mm Giant: $209.95; 11x80mm and 20x80mm Giants: $299.95.

SCOPELINK Wireless Video System

▶ How many times have you set up your scope for video recording and promptly tripped over a coaxial cable in the darkness? Or maybe you've gotten to an observing site only to discover that your video cable is a foot too short. Trango Systems' new SCOPELINK remote video transmission system will turn these and other glitches into problems of the past. Simply hook up SCOPELINK to your CCD camera and you'll instantly be able to transmit high-quality, full-motion color video from your telescope to a receiver up to 1,000 feet away. And with four-channel capability, you'll be able to monitor four sites simultaneously. You need do no more than couple SCOPELINK to a video recorder to make your viewing site equipped for high-performance video recording — and all in a matter of minutes because installation is remarkably easy.

The SCOPELINK video transmission system consists of a 2.4 GHz transmitter/receiver pair, a high-gain receiver antenna, two 12 V d.c. power supplies, and an operator's manual. All components are rated from –4° to 158° F.

Trango Systems, 9939 Via Pasar, San Diego, CA 92126; phone, (619) 653-3900; fax, (619) 621-2725; website, http://www.trangosys.com; e-mail, trango@zcomm.com. SCOPELINK Wireless Video System: $495.

BOOKS

Probability 1 — Why There Must Be Intelligent Life in the Universe

Amir D. Aczel, 240 pages, Harcourt Brace and Company, New York, 1998; ISBN 0-15-100376-9; softcover, $22.

▶ For one practiced in dealing with numbers, Amir Aczel certainly has a way with words. In his most recent work, *Probability 1*, scientist and mathematician Aczel presents a beautiful marriage of mathematics and prose. For as long as there have been thinking beings on Earth, there have been beings thinking about whether intelligent life might exist elsewhere too. Aczel, encouraged by what seems to be the emergence of scientific evidence about this question, sets out to tell the stories of our ever increasing knowledge of the universe. He takes the components contributing to this seemingly imminent scientific answer — the cosmology of Stephen Hawking, the discoveries made by the Hubble Space Telescope, the data coming back from Mars, and new information about life at extreme temperatures — and holds it all together using math as his glue.

Using Drake's equation as a starting point, Aczel cites historical precedent for using math as the tool to prove the existence of intelligent life in the universe. The Drake equation depends on seven factors: the number of stars in the galaxy, the percentage of stars with planets, the number of planets with environments favorable to life formation, the fraction of planets with life, the proportion of those planets with intelligent life, the fraction of those planets with civilizations able to communicate with others, and the

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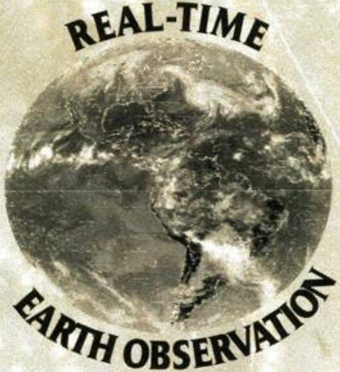

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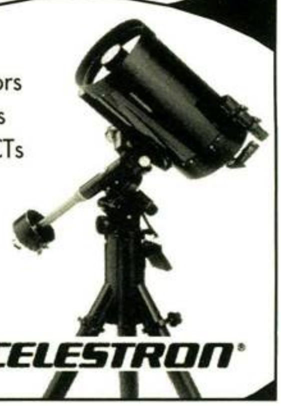

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longevity of the civilization. As Aczel sees it, the possibility of life in the universe is derived from the expanding number of galaxies, the plausibility of life in the universe comes from discoveries of planets, and the probability of life in the universe is increased by our growing understanding of life in hostile conditions, both chemically and thermally. And as he sees it, the way to determine that probability is to draw on Blaise Pascal's rule for the probability of a union of events and apply it to the search for extraterrestrial life: The probability of the existence of extraterrestrial life is equal to 1 minus the probability of no extraterrestrial life, an equation that he solves in his final pages. "The probability is a virtual certainty," he states and backs up with numbers.

Before reading Aczel's book you may find it easy to shrug off his conclusions. After you've finished *Probability 1*, you may find it harder to do so. Whether or not you are ultimately convinced, his fusion of math with delightful prose, all peppered with amusing anecdotes and intriguing history, will make the read worthwhile.

— *Jeanette Brown*

A Practical Guide to CCD Astronomy

Patrick Martinez and Alain Klotz, 243 pages, Cambridge University Press, New York, 1998; ISBN 0-521-59063-9 and 0-521-59959-4; hardcover, $74.95; softcover, $29.95.

▶ With the explosion of CCD (charge-coupled device) cameras onto the amateur astronomy scene in recent years, *A Practical Guide to CCD Astronomy* is a welcome addition to the astronomy library. The book is intended to serve as a coherent, self-contained guide to choosing and using CCD cameras. In a clear and concise introduction to CCD cameras, authors Martinez and Klotz explain how to measure camera performance and demonstrate how to use a CCD camera and how to calibrate the images you obtain. A handy review of the software available for visualizing, analyzing, and processing digital images is also included. And a section highlighting the key areas in astronomy where CCD cameras can best be put to use is peppered with practical tips for creating spectacular CCD images. This book promises to provide novices with a clear introduction to CCD astronomy while simultaneously serving as a useful reference for more experienced amateur astronomers. — *J. B.*

Hubble Vision: Further Adventures of the Hubble Space Telescope

Carolyn Collins Petersen and John C. Brandt, 320 pages, Cambridge University Press, New York, 1998; ISBN 0-521-59291-7; hardcover, $39.95.

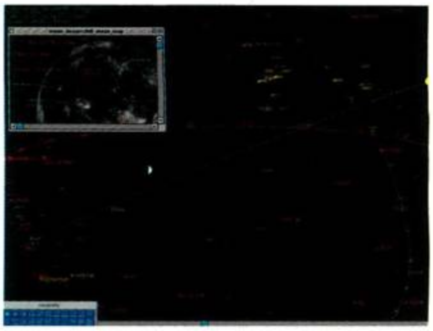
▶ In this, the eagerly awaited second edition of *Hubble Vision*, you will find one of the most comprehensive, authoritative, and expertly illustrated popular books about the Hubble Space Telescope available. In a completely revised, updated, and expanded edition, *Hubble Vision: Further Adventures of The Hubble Space Telescope* includes all of the latest astronomical discoveries — among them supernovae, protostars, gravitational lensing, black holes, and more clues about the early universe — and serves to expand public access to the wonders and treasures held within Hubble's vault of images. The magnificent collection of latest and greatest Hubble images is complemented by clear and fascinating text explaining the most exciting discoveries that have been made. And the pictures alone are enough to make this a must-have book for most — 140 color plates, 30 halftone images, 15 line diagrams, and two tables illustrate how Hubble has helped us to discover the universe in which we live. — *J. B.*

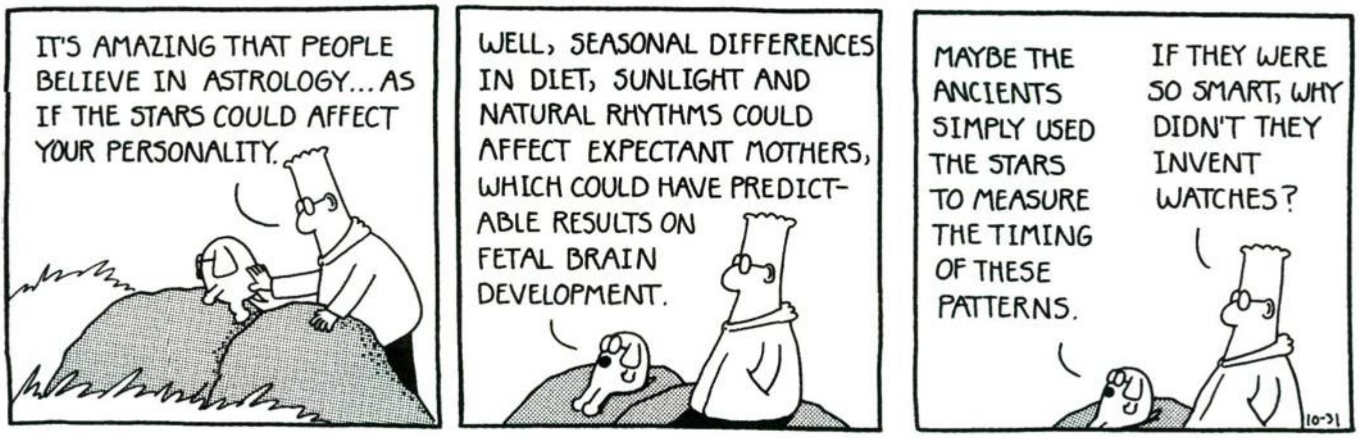
BYTES

Universe Explorer

▶ Its manufacturer asserts that *Universe Explorer* is "the only complete guide to our universe." The creators of other software packages may take issue with this claim, but no one can contest the fact that this impressive CD-ROM package from Rom Tech offers users a full and multi-faceted resource for learning about the cosmos.

The package is in fact a combination of two CD-ROM programs, *Mars*

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MAYBE THE ANCIENTS SIMPLY USED THE STARS TO MEASURE THE TIMING OF THESE PATTERNS.
IF THEY WERE SO SMART, WHY DIDN'T THEY INVENT WATCHES?
10-31

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Hardly a day goes by that we don't get a note or E-mail message like the one reprinted below, or a call that goes something like this: "Your ads are right. So and so on the East Coast advertises low prices – but they don't have what I want in stock, they couldn't answer *any* of my questions, and they wanted my credit card number before they'd even *talk* to me. They said if I wanted to ask questions, I should call the manufacturer . . . and then they hung up on me!" One of our customers added, "If I wanted that kind of abuse, I would have called my ex-wife."

If you want the right telescope, you need more than a camera store clerk with a price list, a surly attitude, and a wild guess.

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Unlike camera stores and shopping mall gift shops, telescopes are our specialty at ***astronomics***, not a sideline. We're a family-owned full-line telescope dealer – not just a few scopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. We don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

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Our free catalog helps you pick the right Meade, Celestron, Questar, Takahashi, or TeleVue.

For detailed information on individual products, visit our Web site. Or you can call us at (405) 364-0858 or E-Mail us for your *free* copy of our catalog 98AST. It covers all of the telescopes and accessories we stock – from Apogee, Celestron, DayStar, JMI, Lumicon, Meade, Optec, Pentax, Questar, Rigel Systems, SBIG, Software Bisque, Takahashi, TeleVue, and more. We'll include our 8-page guide on how to pick the right scope and your discount prices on the 1000+ products we carry. (Sorry, U. S. sales only.) The catalog is yours for only the cost of a one minute telephone call. The information we send will make it the most useful minute you'll ever invest in astronomy.

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>
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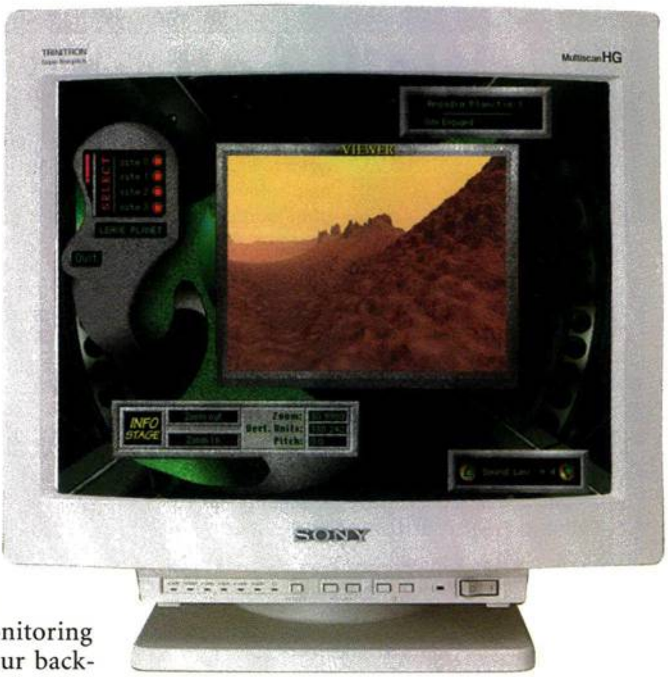
Rom Tech, 2000 Cabot Blvd., Suite 110, Langhorne, PA 19047; phone, (888) 476-6832; website, http://www.romt.com or http://www.mmwhse.com. Price: $19.95 plus shipping and handling. Minimum requirements: Windows — 486DX66, 8 MB RAM, 2X CD-ROM drive, Windows 3.1, 24-bit monitor, 10 MB hard disk space; Macintosh — 68040 processor, 16-bit monitor, 16 MB RAM, 10 MB hard disk space, 2X CD ROM, Quicktime 2.0 (included).



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Columbia Weather Systems, Inc., 3175 NW Aloclek Drive, Hillsboro, OR 97124; phone, (503) 629-0887; fax, (503) 629-0898: website, http://www.columbiaweather.com: $1,650 plus shipping and handling.

The Webweaver Picks

Learn more about this month's Leonid meteor shower and possible meteor storm by visiting the following sites:

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http://web99.arc.nasa.gov/~leonid/

The Leonids
http://medicine.wustl.edu/~kronkg/leonids.html

Association of Lunar and Planetary Observers Meteors Section
http://www.lpl.arizona.edu/~rhill/alpo/meteor.html

Understanding the Leonid Meteor Storms
http://www.aero.org/leonid/

International Meteor Organization: Hints for Observing the '98 Leonids
http://www.imo.net/news/leohints.html

North American Meteor Network: Meteor Observation Guide
http://medicine.wustl.edu/~kronkg/namn/guide.html

North American Meteor Network: Meteor Observing Report forms
http://medinfo.wustl.edu/~kronkg/namn/reports.html

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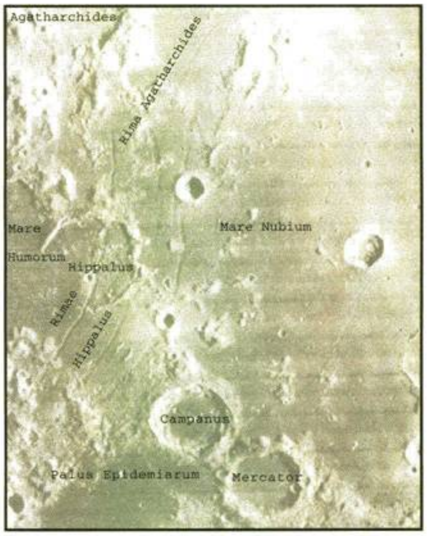

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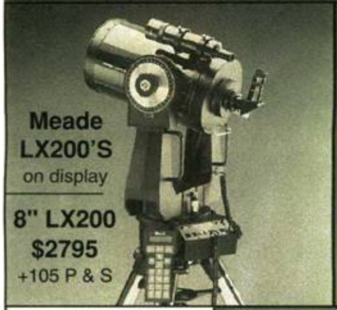

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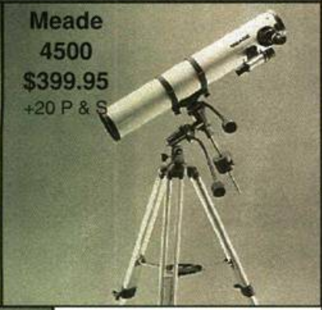

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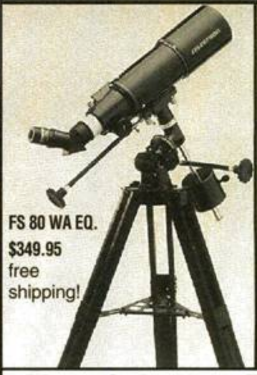

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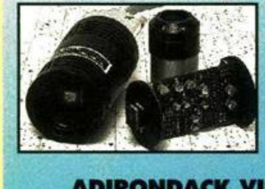

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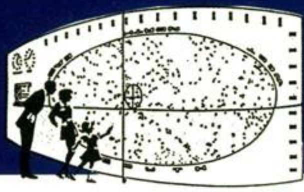

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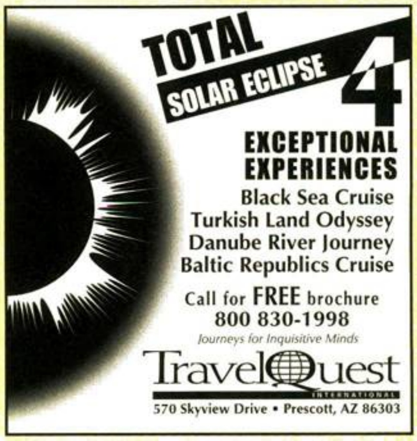

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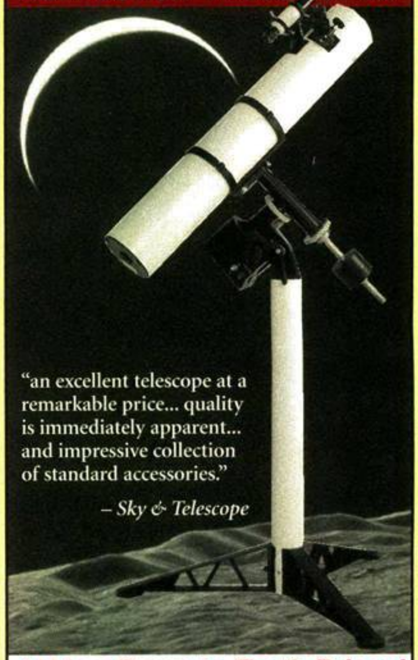

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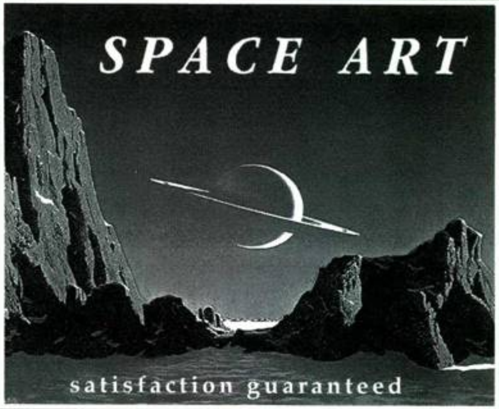

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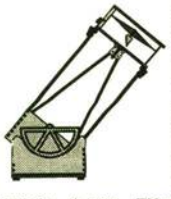

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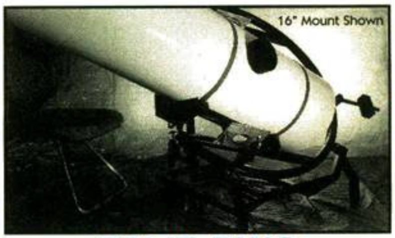

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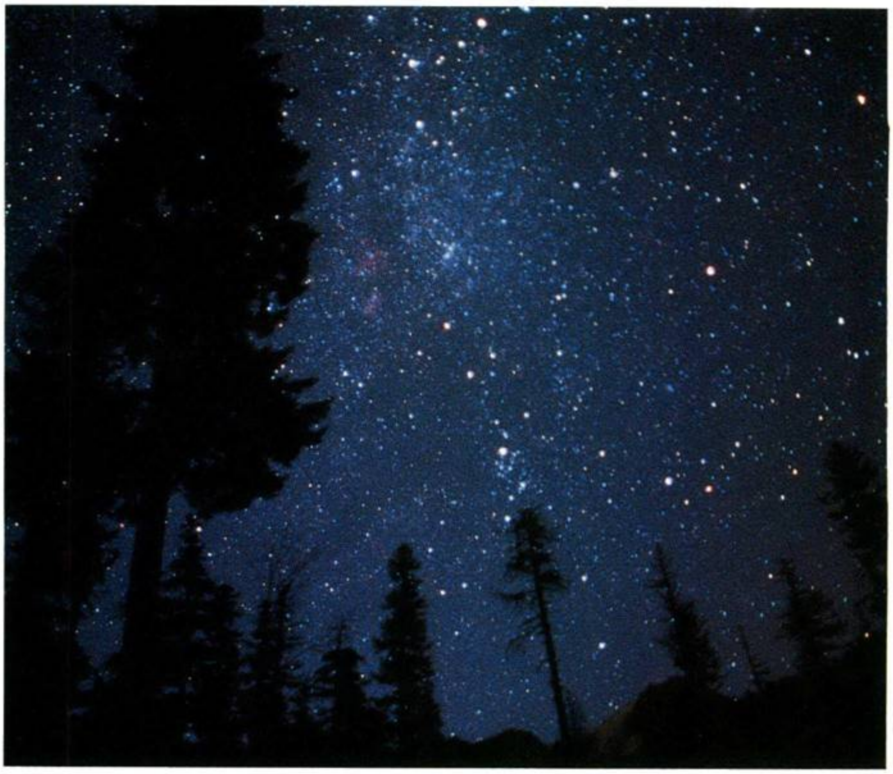
At the **Jersey Astro Conference and Showcase,** taking place **November 7,** Michio Kaku, professor of theoretical physics at the City University of New York and *Astronomy* contributor, will lecture on cosmology. Additional presentations include Tad Prior of Rutgers University discussing Hubble research on globular clusters; Dale Gary of the New Jersey Institute of Technology on solar research; and Mario Runco, NASA astronaut, on photography from space. JACS also features exhibitors and vendors of astronomy products, an astrophotography contest, tours of Sperry Observatory, and more. This is a one-day event you won't want to miss.

It's time to set your plans in motion for the **Winter Star Party, February 15–20,** in the Florida Keys. The call of tropical breezes, palm trees, and clear, dark skies coupled with the promise of a glimpse of the Southern Cross make this ever-popular star party hard to resist in the dead of winter. Registration information can be obtained from the WSP website at http://www.scas.org or by calling (904) 362-5995. For accommodations call (800) FLA-KEYS.


Jerry Schad

Starry night over Mt. Ranier National Park.

OCTOBER 18–24
Okie-Tex Star Party

▶ Prude Ranch, Fort Davis, Texas. Contact the Oklahoma City Astronomy Club, P. O. Box 128, Mustang, OK 73064; Steve Adkins, (405) 722-1678 (eve.); e-mail, seadkins@icon.net; website, http://www.icon.net/~seadkins/okie-tex.html.

OCTOBER 21–24
Great Lakes Planetarium Association Conference

▶ Seasons Conference Center, Nashville, Indiana. For registration material or more information contact Dan Goins, Martinsville High School Planetarium, 1369 E. Gray Street, Martinsville, IN 46151; (765) 342-5571; e-mail, glpa@scican.net.

OCTOBER 22–24
Mt. Magazine Star Party

▶ Mt. Magazine, Arkansas. Sponsored by the River Valley Stargazers. Contact Myron Barnum, 76 Observatory Lane, Dover, AR 72837; (501) 331-3773 (day), (501) 331-3620 (eve.).

OCTOBER 15–20
Mid-Atlantic Star Party (MASP)

▶ Boy Scout Camporee Camp Reeves, south of Robbins, North Carolina. For more information, send a SASE to MASP, 244 Deerfield Road, Apex, NC 27502; (919) 362-5194; e-mail, john@bsa.net; website, http://www.bsa.net/masp/.

OCTOBER 23–24
Blackwater Falls Astronomy Weekend

▶ Blackwater Falls State Park, Davis, West Virginia. Sponsored by the Kanawha Valley Astronomical Society. Contact Ron Cockeram, 5216 Bailey Road, Cross Lanes, WV 25313; (304) 776-5017 or (800) 225-5982; website, http://www.earth1.net/kvas/.

OCTOBER 23–25
Annual Meeting of the Antique Telescope Society

▶ Harvard University, Cambridge, Massachusetts. Contact Walter Breyer, 1275 Poplar Grove Lane, Cumming, GA 30041; e-mail, whbreyer@mindspring.com.

OCTOBER 24, NOVEMBER 16
Free Public Star Party

▶ Ralph A. Worley Observatory, south of Shreveport, Louisiana. Sponsored by the Shreveport-Bossier Astronomical Society. Contact Cran Lucas, (318) 797-1524; website, http://www.lsus.edu/nonprofit/sbas/.

OCTOBER 29–NOVEMBER 1
Annual Meeting of the American Association of Variable Star Observers (AAVSO)

▶ Cambridge, Massachusetts. Contact AAVSO – Meetings, 25 Birch Street, Cambridge, MA 02138; e-mail, meetings@aavso.org; website, http://www.aavso.org.

OCTOBER 30,
NOVEMBER 6, 13, 20, 27
Friday Star Nites

▶ The Hudson River Museum of Westchester, Yonkers, New York. October 30 – The Scary Sky Tonight; November 6 – The Sky Tonight;

November 13 – Return to Mars; November 20 – The Start of It All; November 27 – A Christmas Story. Contact Connie Cullen, Hudson River Museum of Westchester, 511 Warburton Avenue, Yonkers, NY 10701; (914) 963-4550; fax, (914) 963-8558

NOVEMBER 6–7

Imaging the Sky Workshop

▶ Willamette University, Salem, Oregon. Sponsored by the Friends of Pine Mountain Observatory, Rose City Astronomers, and Willamette University. Contact Jim Girard, P. O. Box 254, Beaverton, OR 97075; (503) 643-1813; e-mail, argo@teleport.com; website, http://pmo-sun.uoregon.edu/~pmo/its.html.

NOVEMBER 7

Carl Sagan Day

▶ Birmingham Central Library Lecture Theater, Chamberlain Square, Birmingham, United Kingdom. Sponsored by the Planetary Society. Contact Andrew Lound, 110 Sandringham Road, Great Barr, Birmingham B42 1PQ, UK; telephone, 0121-356-5446; e-mail, hn81@dial.pipex.com; website, http://planetary.org.

NOVEMBER 7

Jersey Astro Conference and Showcase (JACS)

▶ Union County College campus, Cranford, New Jersey. Sponsored by Amateur Astronomers, Inc. Contact JACS, P. O. Box 111, Garwood, NJ 07027; Steve Clark, e-mail, icstars@erols.com; website, www.erols.com/icstars/jacs/.

FEBRUARY 15–20

Winter Star Party

▶ Camp Wesumkee, West Summerland Key, Florida Keys. Sponsored by the Southern Cross Astronomical Society. Contact Fred and Lucille Heinrich, 6165 Wiggins Road, Live Oak, FL 32060; (904) 362-5995; e-mail, astargazer@aol.com.

CONTACT

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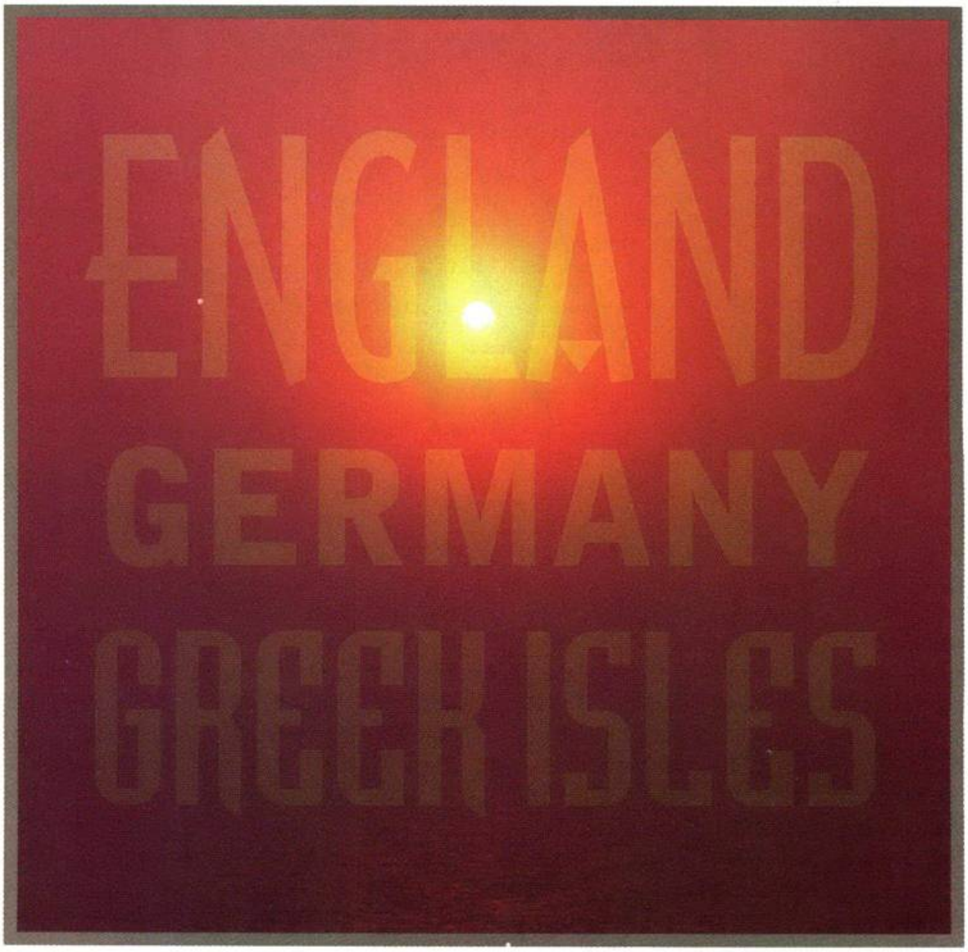

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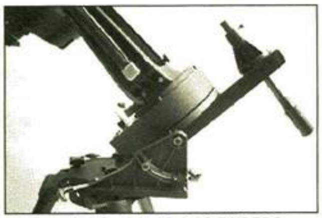

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Doug Hoeschler

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CLUSTER HUNTING

In Search of Omega Centauri

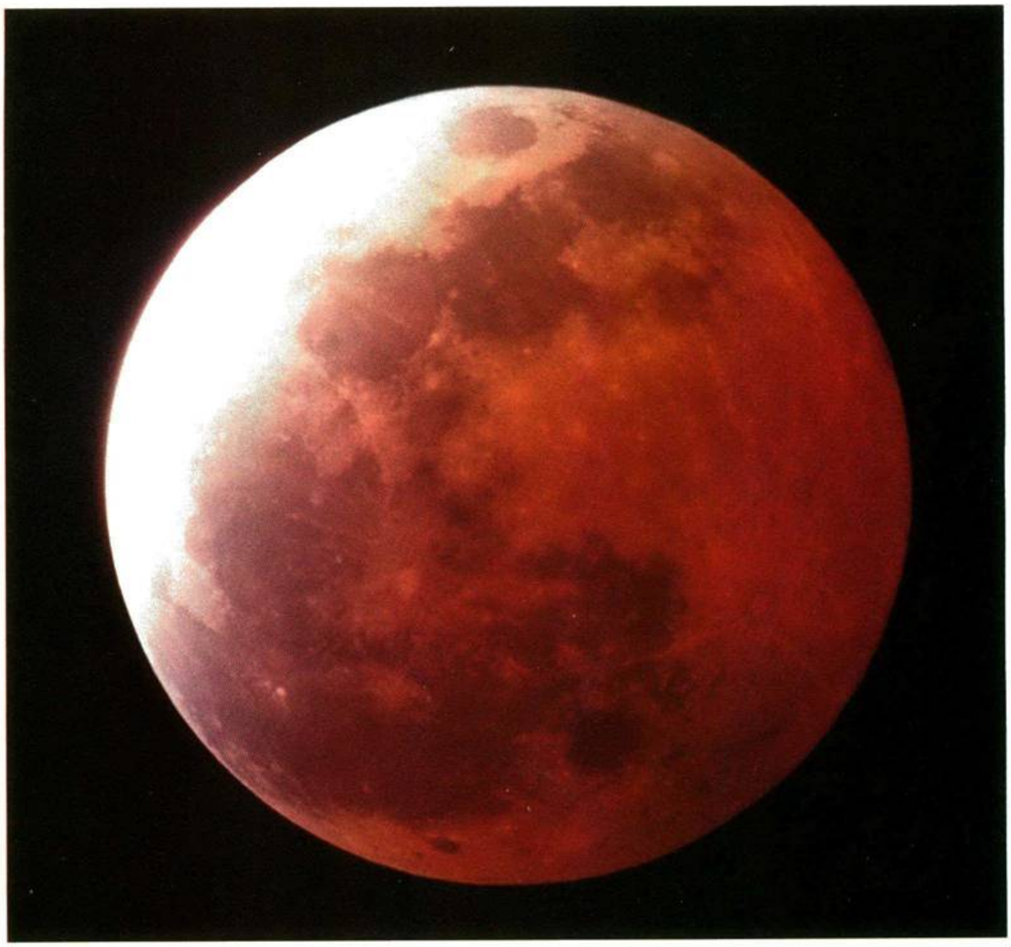
This bright globular opened the door to new adventures.

▶ My husband John is an avid amateur astronomer, and I usually follow in his wake where a knowledge of the heavens is concerned. At our home in Missouri, we have two observatories and an ever growing number of telescopes. To me it seemed insane when one night recently John decided to close up the observatory and leave behind the 14-inch telescope.

The goal? To drive 18 miles from home, walk through dark woods, and climb a fire tower at midnight in hopes of finding a globular cluster that is difficult to see from our northern location. But his cosmic dial was set, and we needed to gain elevation in order to witness Omega Centauri as it clung to the horizon in near obscurity.

The city lights in the southern sky heckled us as we drove to our destination hoping our view wouldn't be washed out by light pollution. Every few minutes I would strain my neck to look at the sky — a black background with dots of light poking through — dots that grew much more distinct once we finally parked and began to walk away from the highway.

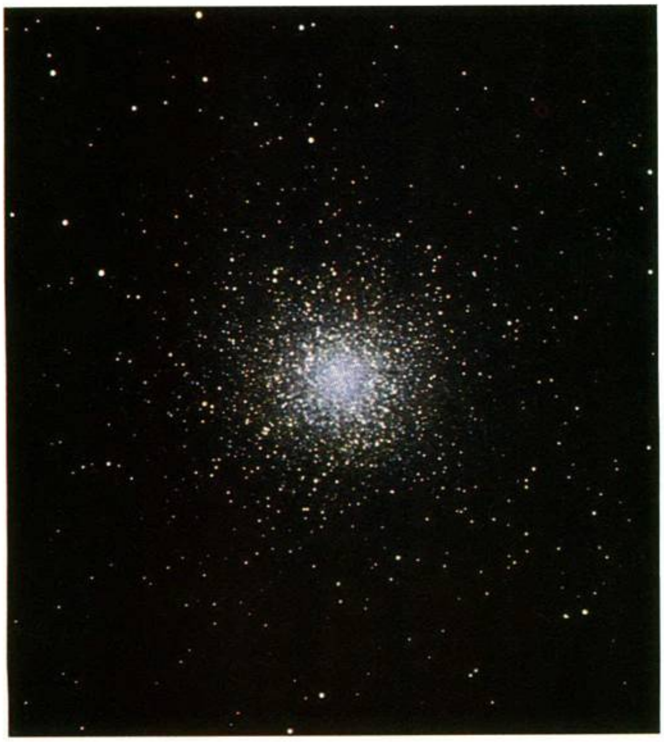
With each step into the quiet night, I grew more excited about the prospect of



The Moon in Mideclipse

JACQUES GUERTIN

(16-inch f/5 reflector, Kodak Royal Gold 400 film, 7-second exposure taken March 23, 1997, from Newark, California)



The Hercules Cluster (M13)

BILL AND SALLY FLETCHER

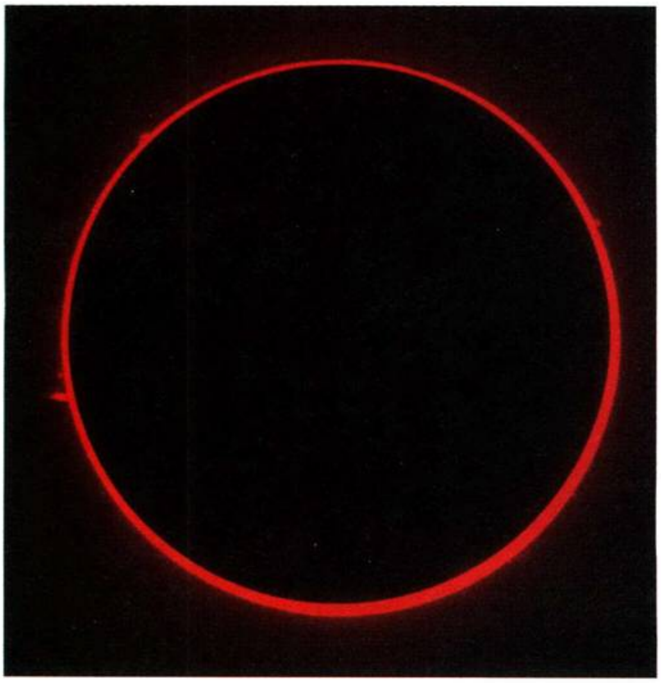
(16-inch f/4.5 reflector, hypersensitized Tech Pan film, composite of 35-minute red, 45-minute green, and 70-minute blue exposures) glimpsing Omega Centauri. As we made our way to the fire tower, the leaves crunching beneath our feet brought the only breaks in the nocturnal silence. The smell of wet earth brought back memories of similar adventures we'd shared in the past.

Omega Centauri resides in a spherical halo of clusters and dark matter around the galaxy, in an elliptical orbit. Some one million stars spread out from its concentrated center, and at magnitude 3.7 it ranks as the brightest globular cluster in the sky. It remains suspended beneath Hydra the Water Snake, keeping a safe enough distance to elude the ravenous appetite of that multiheaded monster.

Standing on top of the fire tower in the dark night I felt almost weightless, but I held my arms steady and kept my eyes fixed on the southern sky. We talked and probed the sky for our cluster until, all of a sudden, it appeared. After several sweeps of the sky, a faint blur came into my field of view. I looked at my watch: Omega Centauri was on time. It looked like the type of smudge a thumbprint makes on clean glass. At a distance of 17,000 light-years, it is one of the nearest globular clusters.

We stayed with Omega Centauri until the cold night air drove us to our car to warm up. As we began to pack up for the evening, I thought back to the smudge my binoculars had earlier revealed to me as Omega Centauri. The sky's best globular cluster left me completely satisfied. ■

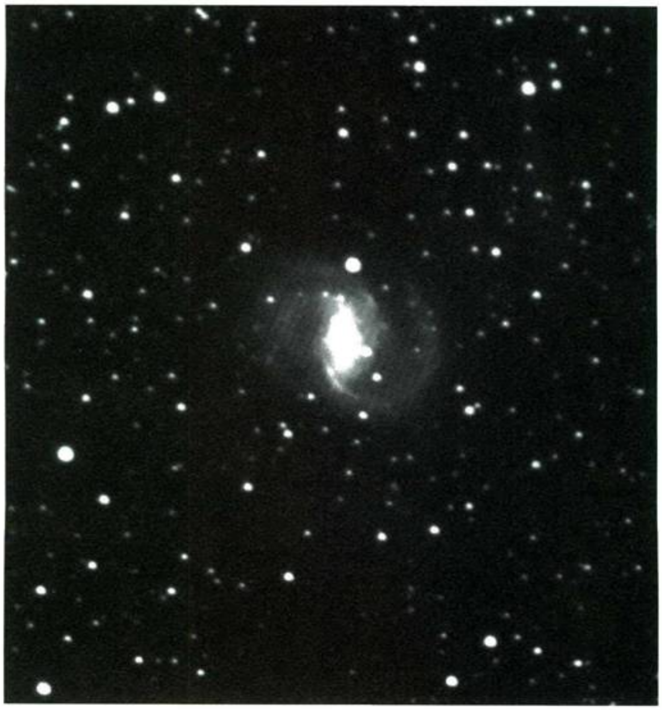
Carolyn Hudler, following her husband, is becoming an avid skygazer.



Prominences Jump from the Sun's Limb

FRANCESCO ALFÉ, G. TUMINO, AND P. GRANDE

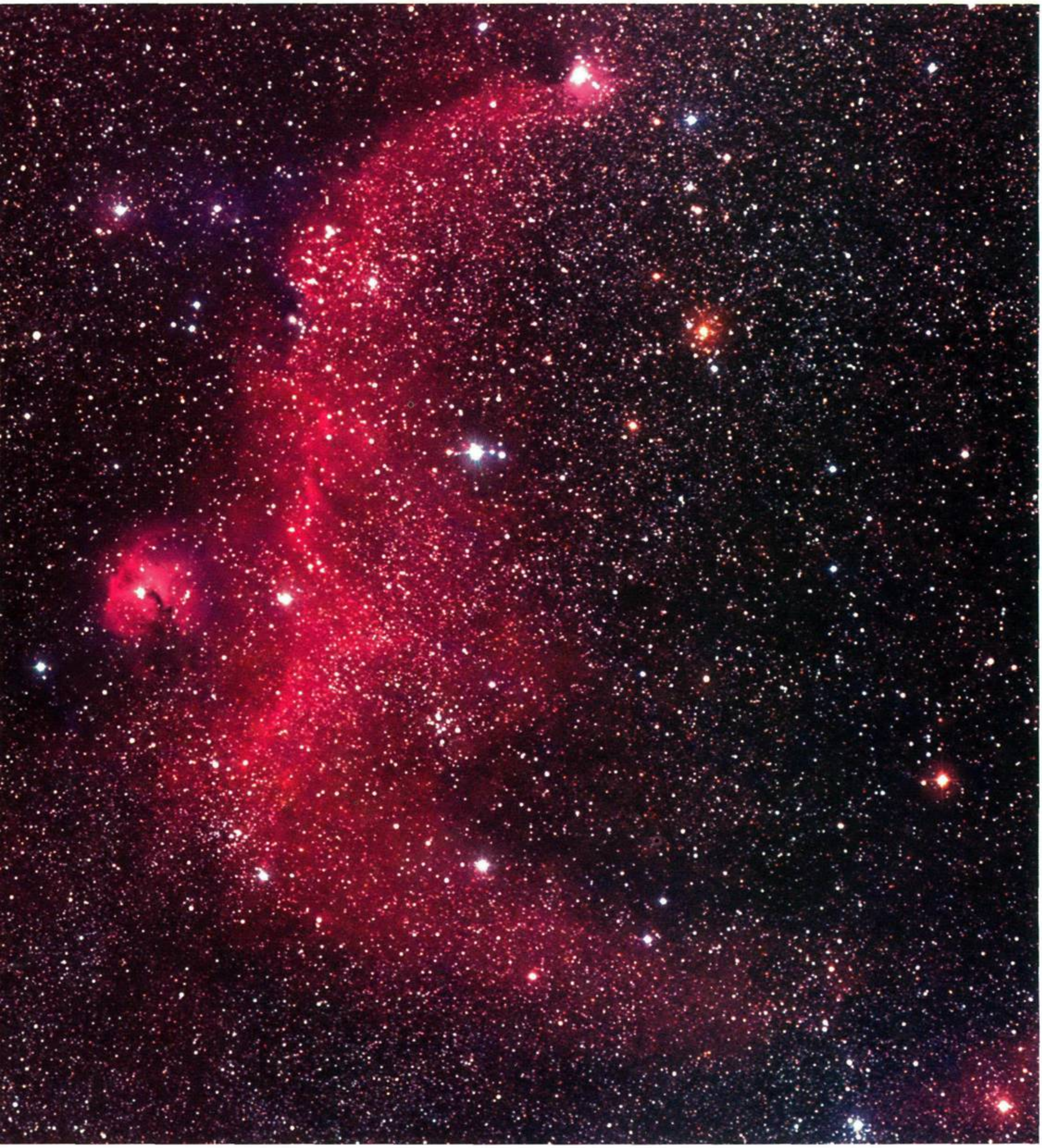
(6-inch f/10 refractor, 2.5-angstrom Hα coronagraph, Fuji Provia 100 film, 1/60-second exposure taken June 30, 1996)



Spiral Galaxy NGC 6951 in Cepheus

MARTIN C. GERMANO

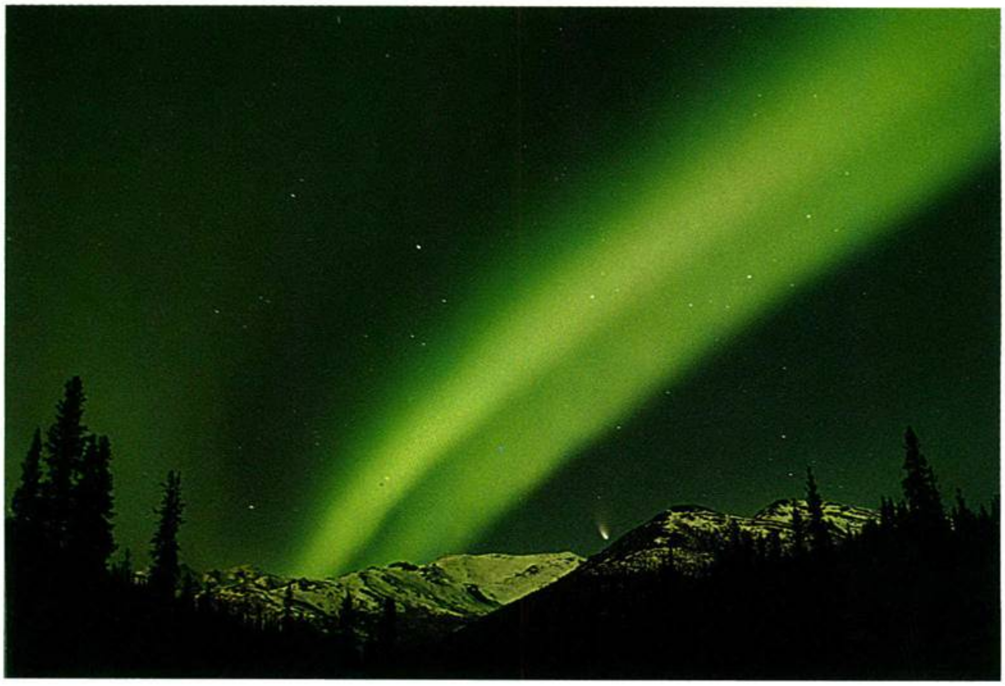
(14.5-inch f/5 reflector, hypersensitized Tech Pan film, 140-minute exposure)



The Seagull Nebula (IC 2177)

BILL AND SALLY FLETCHER

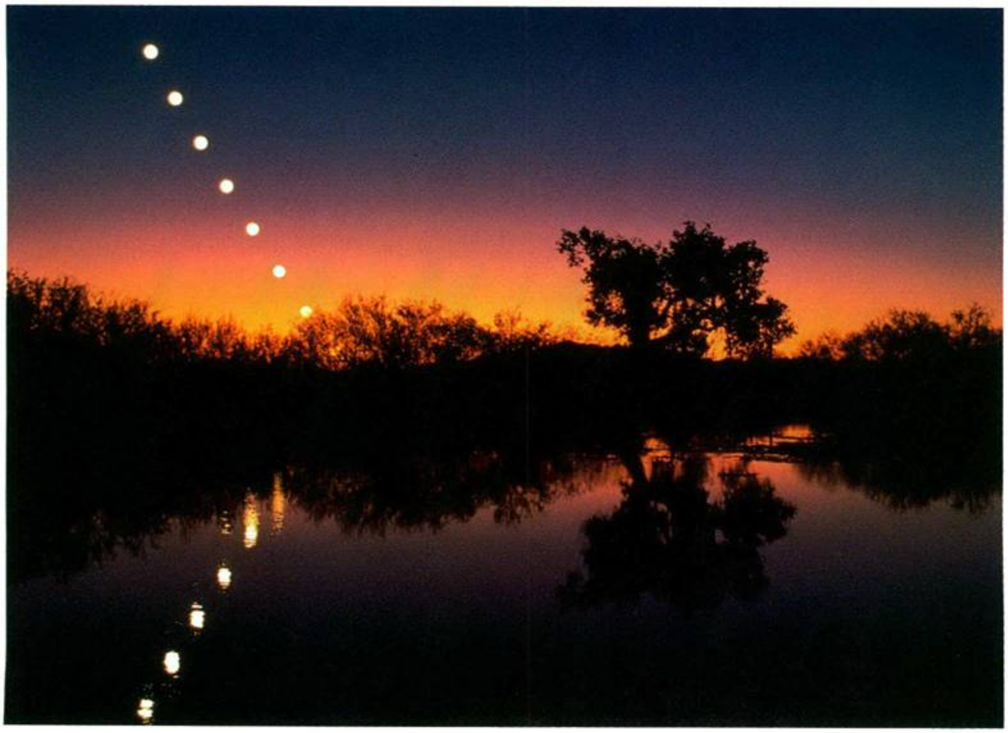
(8-inch f/1.5 Schmidt camera, Tech Pan film, composite of 15-minute red, 58-minute green, and 68-minute blue exposures)



An Aurora Joins Comet Hale-Bopp

MICHAEL KLENSCH

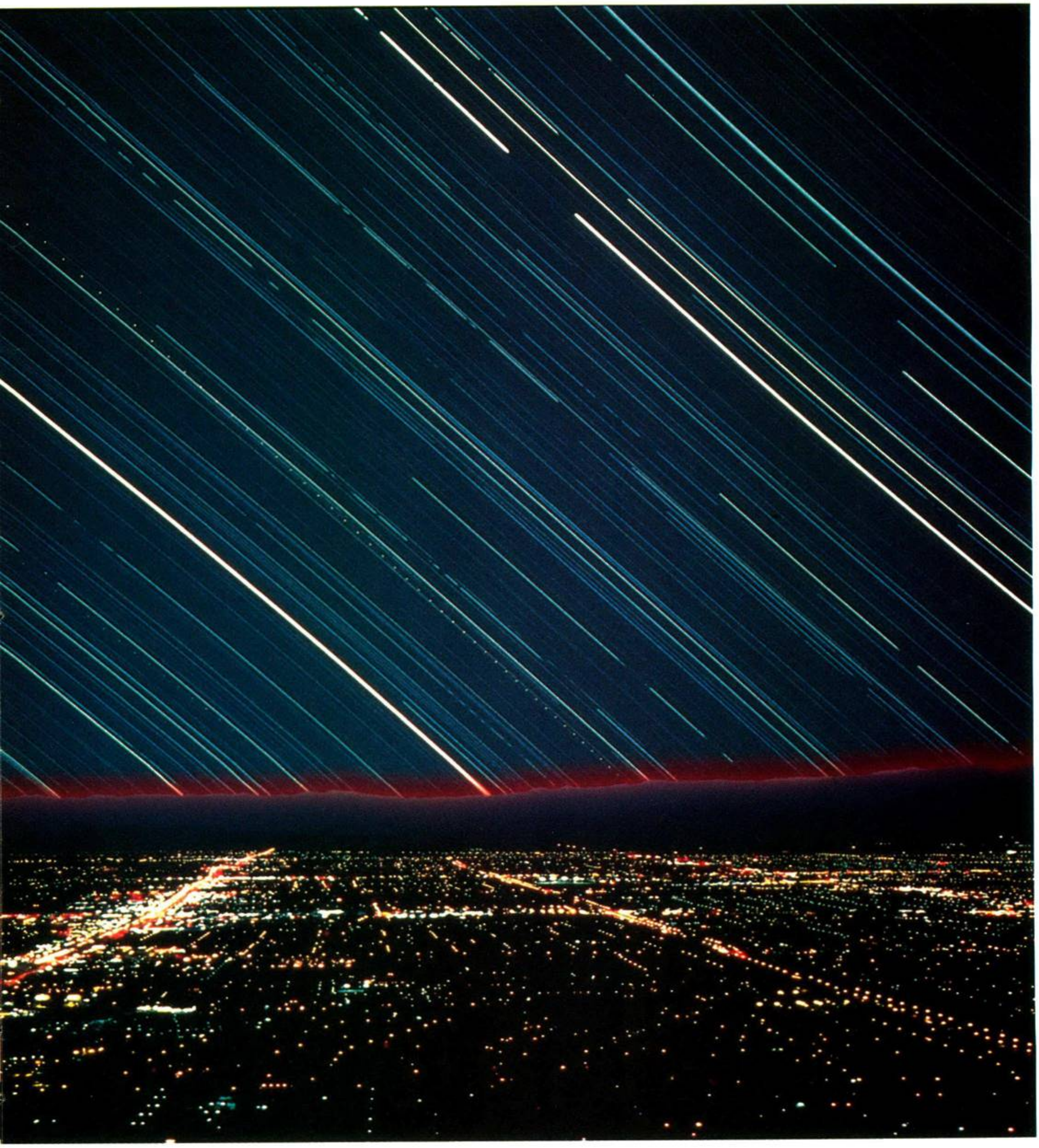
(38mm lens at f/2.8, Fuji 100 ISO film, 10-second exposure taken April 17, 1997, from Denali National Park, Alaska)



The Sun Sinks into Quitobaquito Oasis, Organ Pipe Cactus National Monument, Arizona

FRANK ZULLO

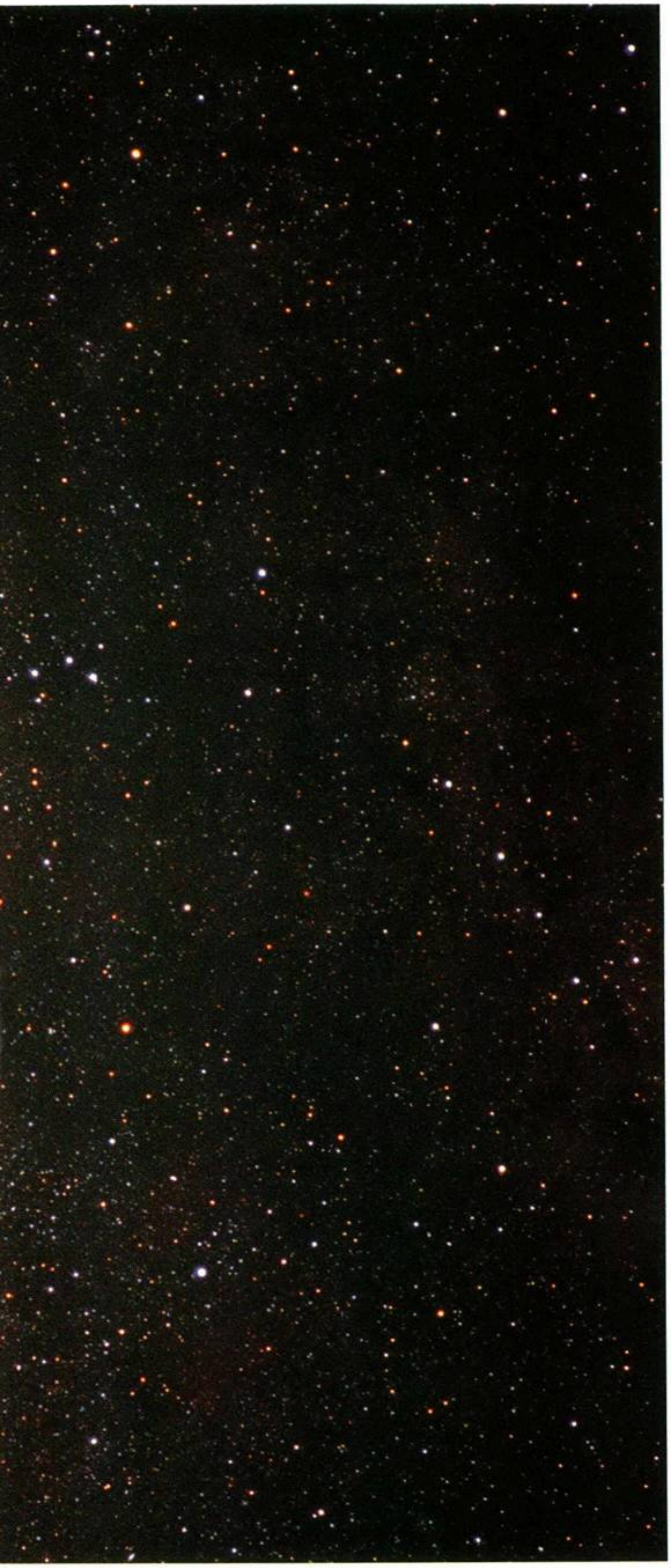
(55mm lens at f/8, Fuji Velvia film, ND 3 filter, series of 1/500-second exposures; last exposure, 1-second at f/5.6, taken in 1995)

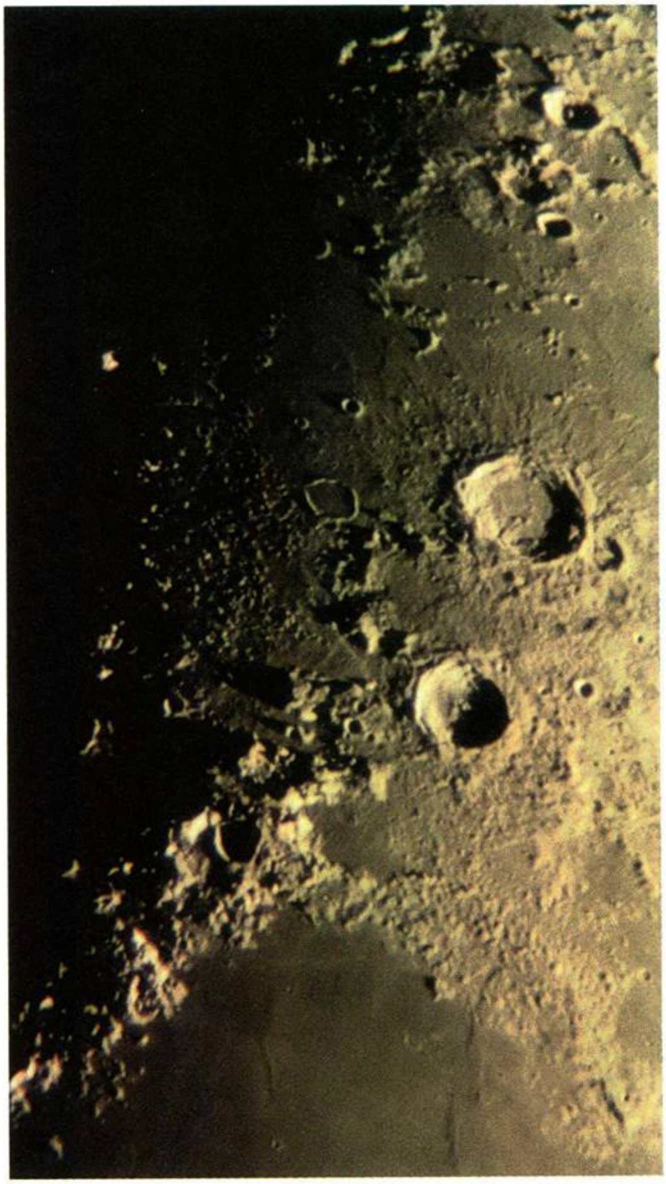


Star Trails over City Lights

DALE O'DELL

(composite photo of star trails and city made separately and co-added in Adobe Photoshop)





Sunlight Kisses Craters Aristotle and Eudoxus

PHILIP A. TOREN

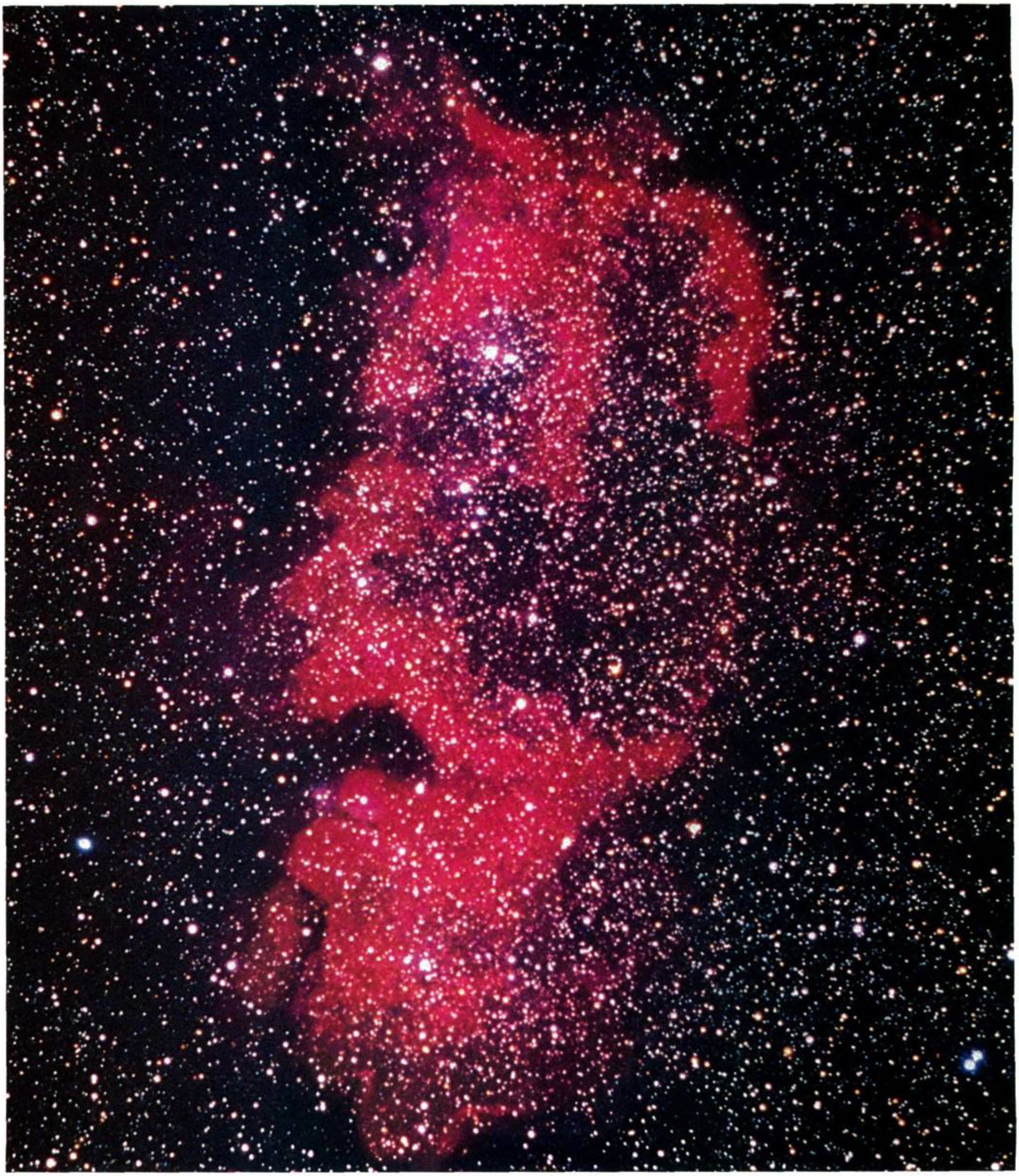
(6.1-inch f/12 refractor, KRG 200 film, ¾-second exposure taken March 15, 1997)

The Lagoon and Trifid Nebulae

GIANNI TUMINO

(200mm lens at f/4, Ektachrome 200 film pushed to ISO 1000, composite of two 20-minute exposures)

This month's best astrophoto



Emission Nebula IC 1848 in Cassiopeia

MICHAEL STECKER

(5-inch f/6 apochromatic refractor, hypersensitized Fuji HG 400 film, *composite of two 45-minute* exposures) This vast expanse of emission nebulosity is birthing the rich star cluster embedded within. The brightest stars in the cluster are O-type supergiants dozens of times more luminous than the sun.

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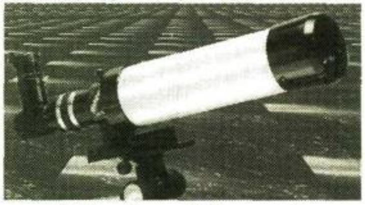

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Photo of Horsehead Nebula taken with Pronto by Ralph Sieger

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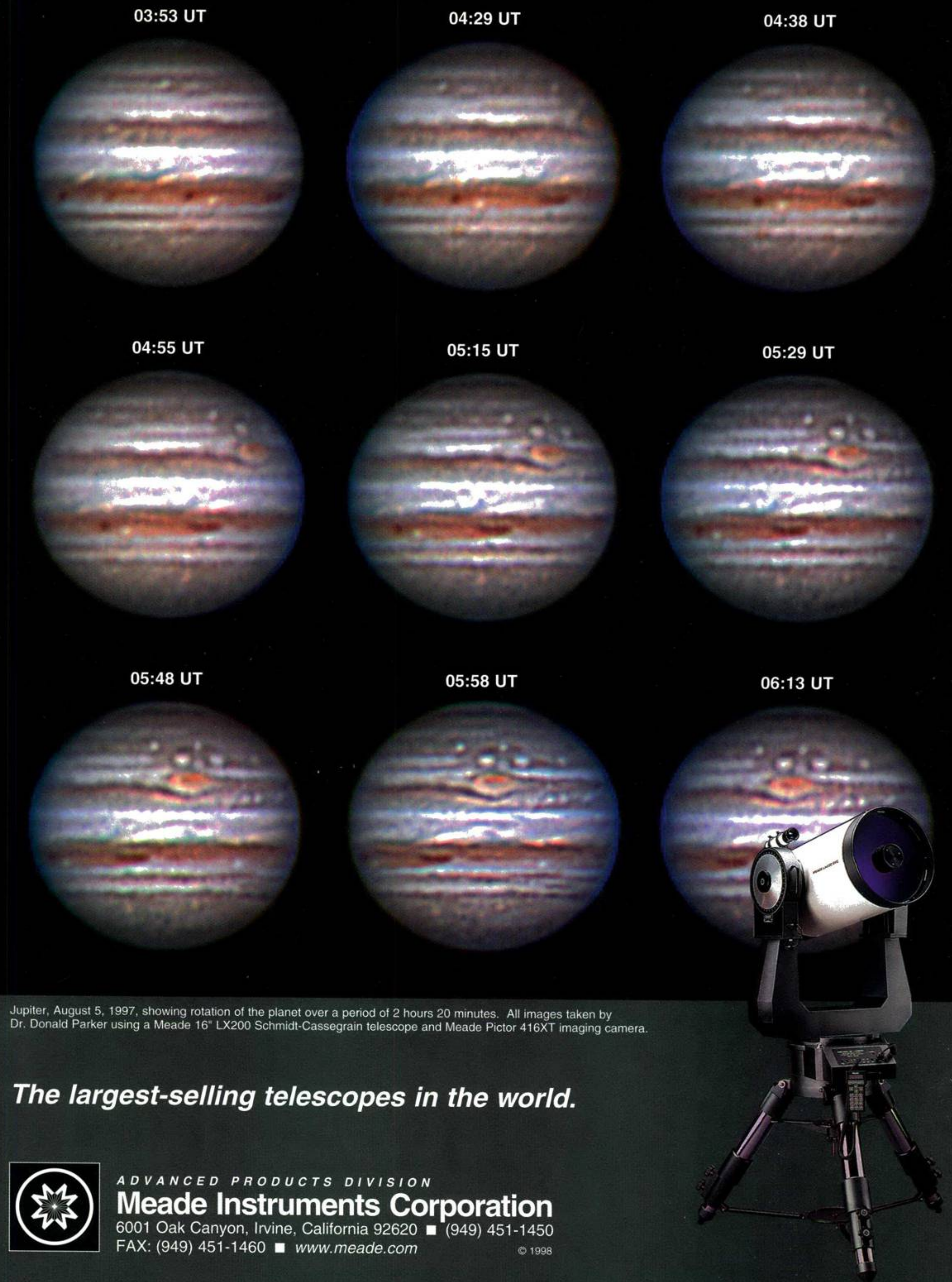
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Jupiter, August 5, 1997, showing rotation of the planet over a period of 2 hours 20 minutes. All images taken by Dr. Donald Parker using a Meade 16" LX200 Schmidt-Cassegrain telescope and Meade Pictor 416XT imaging camera.

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